[COMMITTEE PRINT]

UNITED STATES AND SOVIET PROGRESS IN SPACE: SUMMARY DATA

REPORT

PREPARED FOR THE

SUBCOMMITTEE ON
SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
NINETY-FIFTH CONGRESS
SECOND SESSION

BY THE

SCIENCE POLICY RESEARCH DIVISION
CONGRESSIONAL RESEARCH SERVICE
LIBRARY OF CONGRESS

Serial DD

APRIL 1978

Printed for the use of the Committee on Science and Technology

U.S. GOVERNMENT PRINTING OFFICE
24-497 O WASHINGTON : 1978

For sale by the Superintendent of Documents, U.S. Government Printing Office
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LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, D.C., April 1978.

Hon. OLIN E. TEAGUE,
Chairman, Committee on Science and Technology, House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: Forwarded herewith is a report entitled "United States and Soviet Progress in Space: Summary Data Through 1977 and A Forward Look" prepared by Dr. Charles S. Sheldon II, Chief, Science Policy Research Division, Congressional Research Service, Library of Congress.

Dr. Sheldon's report constitutes the most authoritative review of the Soviet space program in the open literature. Because of its significance as a reference and comparison to the United States space program, I recommend its publication as a Committee print for the use of the Committee.

Sincerely,

DON FUQUA,
Chairman, Subcommittee on Space Science and Applications.

UNITED STATES AND SOVIFT PROGRESS IN SPACE: SUMMARY DATA THROUGH 1977 AND A FORWARD LOOK

CHARLES S. SHELDON II
Chief, Science Policy Research Division

January 23, 1978

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I. INTRODUCTION

Since October 4, 1957 when Sputnik 1 was put into orbit by the Soviet Union, the question of Soviet-American rivalry in space and its broader implications have been matters of public concern, waxing and waning with the irregular occurrence of new space spectaculars, followed by periods of relative quiet between major flights when work proceeded in the laboratories and factories. Sometimes the questions raised by space events have been matters of serious economic and military concern; sometimes they have been domestic and international political issues.

The purpose of this brief paper is to summarize how far these two major space powers have come in the last twenty years, to provide answers to frequently raised questions about the comparative aspects of the two programs, and, further, to look at possible future developments.

The space program is no subject of minor concern. By September 30, 1978, the United States expects to have spent about $100 billion on its combined civilian and military space programs, and over half a million people have been employed directly in our space endeavors. No corresponding data are available from the Soviet Union because of their policies of secrecy in this regard, but considering the physical evidence of space activity, the likelihood is that in real terms, they have committed a similar amount of resources.

This new edition of what has become an annual review has gone "metric" in all quantitative measurements, to conform to NASA and Soviet practice. (See X - Appendix, for conversion table.)

II. BRIEF HISTORY

A. World War II

Building upon a foundation of scientific principles common to much of the world, the Germans developed to a high degree of engineering success the technology of long-range guided rockets, of which the V-2 was the most spectacular. At the end of the war, most of the leading German rocket scientists and engineers surrendered to the United States, while smaller numbers and the Peenemunde missile development center came under Soviet control. The German experience stimulated interest in rocketry, and their practical knowledge was quite useful, but it would be a mistake to judge the primary rocket programs of either the United States or the Soviet Union as depending exclusively upon this captured talent. The Russians in particular had a strong tactical rocket program in World War II, and as they moved into long-range ballistic missiles and space, they did not use Germans directly in their work on any significant scale.

B. The International Geophysical Year (IGY)

In 1955 both the United States and the Soviet Union announced their intentions to launch by 1957 small scientific satellites as a contribution to world understanding of Earth and space physics. The U.S. project was to be called Vanguard, with a payload of about 9 kilograms. Fewer details were available about Soviet plans.

C. Sputnik vs. Vanguard and Explorer

The general public, and many specialists who might have known better, were caught off guard when Sputnik 1 was placed in Earth orbit, with a weight of 84 kilograms. Few had supposed that the "backward" U.S.S.R. would beat the scientifically-advanced United States in this particular endeavor. One Western reaction was that this and subsequent Soviet achievements were fakes; and another reaction was one of near panic with thoughts of bombs dropped from orbit. Sputnik 2, launched November 3, 1957, did not help U.S.

complacency when it was disclosed to weigh 508 kilograms, and to carry a live dog, Layka. U.S. discomfiture, at the very least, was heightened by the explosion on the pad of the widely-advertised first launch attempt of a 2-kilogram Vanguard on December 6, 1957. On May 15, 1958, Sputnik 3 went into orbit as a comprehensive orbital laboratory of 1,327 kilograms. Meanwhile the United States had outpaced its own Vanguard series (Navy-built for the National Academy of Sciences) with Explorer 1 (Army-built) of 8 kilograms payload on January 31, 1958 (Eastern Standard time). Vanguard 1 was launched March 17, 1958.

D. Moon flights, Luna 1-3 vs. Pioneer and Ranger

In 1958, the United States began a double series of Pioneer flights -- one to photograph the far side of the Moon and the other to fly by it. All four launch attempts in that year failed to reach the Moon. In January 1959, the Russians launched Luna 1 which sent 361 kilograms past the Moon (apparently a miss) to circle the Sun. The U.S. National Aeronautics and Space Administration (NASA) followed in March 1959 with its 6 kilogram Pioneer 4 which went by the Moon and circled the Sun. U.S. plans then were to follow up with four more, larger Pioneer series lunar orbit flights during the course of 1959 and 1960, but all of these failed to reach even Earth orbits. In fact, NASA did not reach the Moon until an early Ranger fell on the far side of the Moon (Ranger 4 in 1962). In September 1959, the Soviet Luna 2 struck the Moon near its visible center, delivering metal plaques bearing the Soviet coat of arms. Luna 3 in October 1959 flew by the Moon and by automatic means tooks photographs of the far side, never seen before, which were returned to Earth by radio facsimile. Still later, the U.S. Ranger 7, 8, and 9 flights in 1964-1965 returned spectacular TV pictures of the Moon up to the moment of impact.

E. Manned orbital flight, Vostok vs. Mercury

While Mercury was still in its testing stage in the United States, with the goal of placing a man in Earth orbit for a nominal three orbits in a 1,360 kilogram ship,

the Soviet Union moved more rapidly in this field, too, by exploiting its then larger launch vehicles. Starting in May 1960, test flights of a 4,700 kilogram ship were conducted, with the first successful recovery of two dogs in August of that year. On April 12, 1961, Yuriy Gagarin was placed in orbit in Vostok 1 for a single circuit of the Earth, and in the following August, German Titov repeated the flight but for 17 orbits.

Alan Shepard on May 5, 1961 in a Mercury Redstone (Freedom 7) had flown for 15 minutes about 480 kilometers downrange from the Cape. "Gus" Grissom repeated this type of flight on July 21, 1961. But John Glenn was the first American to make it all the way to orbit with his three loops on February 20, 1962 in a Mercury Atlas (Friendship 7).

The Soviet Union flew the next two sets of Vostok flights in pairs in 1962 and 1963, with a near co-orbit in one case and a near pass in the other. Valentina Tereshkova, the only woman to go into space, in her 48 orbits (with Vostok 6) gained more orbital time than all six Mercury astronauts combined (34 orbits).

F. Gemini vs. Voskhod

The Russians were able to achieve some more firsts with Voskhod 1 in October 1964 which carried the first three man crew, and Voskhod 2 in March 1965 which provided the first 10-minute "space walk" (EVA) by Leonov. But after that the balance swung fairly sharply to the United States which conducted ten successful Gemini flights without any Soviet manned flights in the same period (1965-1966). U.S. two-man Gemini ships of about 3,600 kilograms weight were able to maneuver to change orbit, to rendezvous, and to dock with Agena target vehicles on several occasions. Using the Agena as a pusher rocket, Gemini flew as high as 1,369 kilometers, a new record. The United States, also gained about 12 hours of EVA experience.

G. Apollo and Soyuz Tragedies

Before NASA could make the first manned launch with Apollo, there was the disastrous Apollo fire of January 27, 1967 which took the lives of three astronauts. This was both a great shock to the Nation and set back the program almost two years.

The Soviet Union had its own tragedy on April 24, 1967 when it tried to recover its first manned flight of the new Soyuz series. The parachute lines in the final phase of recovery became twisted, and Vladimir Komarov became the first human being to be killed in return from a space flight. This set back the Soviet program almost two years also, and the shock of this accident was taken very hard by the Russians.

At the end of the Soyuz 11 mission, on June 29, 1971, as the three man crew went through the routines for return to Earth, they fired explosive bolts to separate their orbital work compartment and service module from the recoverable command module. Unfortunately, a valve linking the two habitable compartments remained open at separation, and the men quickly were asphyxiated. Their capsule landed automatically, but they were dead.

H. The Successful Apollo program

After test flights in Earth orbit, NASA took the bold step on December 21, 1968 of launching Apollo 8 with Frank Borman, James Lovell, and William Anders on the first manned Saturn V for ten close orbits of the Moon. The Apollo 11 flight, launched July 16, 1969, permitted Neil Armstrong and "Buzz" Aldrin to become the first men to set foot on the lunar surface on July 20, while Mike Collins orbited overhead.

Apollo 13, launched April 11, 1970, provided the most harrowing Moon mission when an explosion in the service module disabled some systems and cut consumable supplies, so that the crew, committed to going on, circumnavigated the Moon, using the lunar landing module as a lifeboat for all but Earth reentry.

The final flight, Apollo 17, launched on December 7, 1972, was the sixth successful manned landing, and the third to use a roving manned vehicle on the surface.

I. Soyuz flights

Soyuz manned flights resumed in October 1968, and by January 1969 had been used to dock two ships together (Soyuz 4 and 5), permitting crew transfer through EVA. Soyuz 6,

7, and 8 by October 1969, made a group coorbital flight with seven men but no dockings. Soyuz 9 set what was then a duration record by staying in orbit 18 days with a two-man crew. Soyuz 12 was a manned diagnostic flight after the Soyuz 11 tragedy. Soyuz 13 of December 1973 was a manned astronomical observatory flight. Soyuz 16 of December 1974 was a trial run for the Apollo-Soyuz flight to follow. Soyuz 22 in September 1976 was a manned Earth resources flight using a multispectral camera system from the German Democratic Republic.

J. The Soviet circumlunar program

It had been expected in the mid-1960's that the Russians would be the first to send men around the Moon, if not make a landing. Their program did not hold to such a timetable, but was able to send unmanned versions around the Moon for return to Earth. Spaceships named Zond 4 through 8 made flights to lunar distances, and returned either to the Soviet Union or the Indian Ocean where they were picked up. The Zonds resembled Soyuz spacecraft without the orbital work compartment, and they were launched by a more powerful (D) rocket. The program was abandoned before men were carried, probably partly because of uncertainties in man-rating the launch vehicle, and partly because the continued successes of Apollo landings made the Soviet circumlunar flights seem less pioneering.

K. Salyut space stations

The Salyut 1 space station of 18.6 tons was placed in orbit on April 19, 1971. It had about 100 cubic meters of interior space, compared with 6 in Apollo, 9 in Soyuz, and 357 in the American Skylab (see below).

Soyuz 10 was launched with a crew of three, docked with Salyut, but for unstated reasons they were not able to enter the station, so returned to Earth in 2 days. Soyuz 11 was also docked, and its mission ran 24 days long, successfully conducting medical, Earth resources, and astronomical experiments. This was the crew that died during preparations to reenter the atmosphere.

Salyut 2 failed early in its mission, after launch on April 3, 1973. This was followed by Kosmos 557, launched May 11, 1973, intended to be a Salyut, but which failed as it reached orbit.

Salyut 3 was launched July 3, 1974, and differed from Salyut 1 in being a military vehicle by strong implication. (Indicators: An all military crew, telemetry and frequencies akin to other military flights, and a low orbit to improve Earth picture resolutions.) It was visited by Soyuz 14 during a 16-day flight. Soyuz 15 also went up to the station but was not able to dock and returned to Earth after only two days. The station continued to function in automatic mode and returned a data capsule in September 1974.

Salyut 4, launched December 26, 1974, was another civilian mission, flying higher than the military type, using the usual manned-flight frequencies and open communications. Soyuz 17 made a 30-day flight, with the crew in the station. On April 5, 1975, a Soyuz was launched to carry a crew to Salyut 4, but a problem in the booster rocket required an automatic abort which brought the crew back to Earth (unharmed) about 20 minutes after launch. Soyuz 18 followed, and conducted a 63-day mission, the Soviet duration record so far. Soyuz 20 in November 1975 was the first automated, unmanned "resupply" mission to a station (Salyut 4).

Salyut 5, another military station, was launched June 22, 1976. Soyuz 21 was launched on July 6, and conducted a 49-day mission with the crew occupying the station. On October 14, Soyuz 23 attempted a revisit to Salyut 5, but was not able to complete the rendezvous, and returned to Earth after two days. Subsequently, on February 7, 1977, Soyuz 24 was launched on an 18-day mission and the crew reoccupied the station.

Salyut 6, an improved civilian station, was launched on September 29, 1977. On October 9, Soyuz 25 carried a crew up to enter the station, but a hard lock in the docking was not achieved and the crew brought their Soyuz to Earth two days after launch. Another attempt was made on December 10, with Soyuz 26, and this time the

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crew was able to enter the station, for the first time entering a new airlock at the opposite end of the station. (On January 10, 1978, another crew in Soyuz 27 also was sent to orbit to join the previous crew, a new development in the Salyut program.)

L. Skylab Missions

After Apollo Moon flights ended, the United States used a spare Saturn V to place in orbit a modified S-IVB stage equipped as a space station. This was on May 14, 1973. Three Saturn I B vehicles were used to send up modified Apollo ferry craft to dock with Skylab. These missions lasted 28, 59, and 84 days respectively. A wide range of experiments was conducted successfully, especially impressive since the crews had to make difficult repairs to the station damaged during launch.

M. Apollo-Soyuz test project

As a contribution toward detente, and as a spur to the development of a universal, androgynous docking system, the United States and Soviet Union agreed to work cooperatively to develop and to conduct a joint flight in which an Apollo carrying a special docking module would rendezvous and dock with a modified Soyuz. The flights began on July 15, 1975. The Soyuz 19 was sent up from Tyuratam with Leonov and Kubasov, and the Apollo from the Kennedy Space Center with Stafford, Slayton, and Brand. The two crews paid exchange visits after docking and did joint experiments with the Soyuz returning to Earth after 6 days and the Apollo after 10 days.

N. Summary table of space flights

The table which follows gives annual totals for space launchings, payloads in Earth orbit, and payloads sent to the Moon or planets. The figures on successes are reasonably reliable because of requirements for registration at the United Nations, although there are some differences of interpretation in counts on pick-a-back payloads and whether orbiting platforms from which further launches are made should be counted as payloads.

The data on space failures are much more problematical. The United States publishes a launch failure count but not a count of payload losses. The Soviet Union (and presumably China) do not publish failure records. Hence, the table has to assume that the total Soviet failure count is in the same proportion to successes as applies in the United States; further, there is a reasonably safe inferential count of Soviet deep space payloads which became stranded in Earth orbit, whose total even exceeds the expected proportionate share comparable to U.S. experience.

Further details of interpretation of the contents of this table are contained in more comprehensive congressional documents such as the Senate Aeronautical and Space Sciences committee print reviewing the Soviet space program through 1975.

TABLE 1 -- Worldwide Record of Known Space Launchings

SUCCESSES

Year	Launches								Payloads to Earth Orbit								Moon, Beyond	
	US	USSR	France	Japan	China	Italy	UK	Australia	US	USSR	France	Japan	China	Italy	UK	Australia	US	USSR
1957		2								2								
1958	5	1							5	1								
1959	10	3							9								1	3
1960	16	3							16	3							1	
1961	29	6							35	7								1
1962	52	20							55	25							4	1
1963	38	17							62	19								1
1964	57	30							69	37							4	2
1965	63	48	1						93	68	1						4	7
1966	73	44	1						94	47	1						7	5
1967	57	66	2			1		1	78	74	2			1		1	10	1
1968	45	74							61	81							3	4
1969	40	70							58	76							8*	4
1970	29	81	2	1	1				36	98	3	1	1				3	5
1971	31	83	1	2	1	1	1		45	107	1	2	1	1	1		8	7
1972	31	74		1					33	106		1					8	3
1973	23	86							23	122							3	7
1974	22	81		1		2			27	111		1		2			1	3
1975	28	89	3	2	3				30	135	4	2	3				4	4
1976	26	99		1	2				33	139		1	2				1	2
1977	24	98		2					27	125		2					2	
Total	699	1075	10	10	7	4	1	1	889	1383	12	10	7	4	1	1	72	60

*Additionally, the U.S. sent one piece of debris of an Earth orbital flight to escape. Four U.S. launches were performed by Italy.

TABLE 1 -- Worldwide Record of Known Space Launchings (continued)

FAILURES

Year	Launches							Payloads to Earth Orbit							Escape Payloads to Moon, Beyond	
	US	USSR	France	Japan	China	UK	ELDO	US	USSR	France	Japan	China	UK	ELDO	US	USSR
1957	1							1								
1958	12							8							4	
1959	10							9							2	
1960	13	2+?						12	2+?						2	2
1961	12							12							2	1
1962	7							12							1	5
1963	8							11								2
1964	7							8								1
1965	7							7							1	2
1966	4			2				12			2				1	1
1967	3			1				4			1					3
1968	3						1	15						1		
1969	1			1			1	1			1			1	1	2
1970	1			1		1	1	1			1		1	1		1
1971	3		1				1	2		1				1	1	1
1972	2							2								1
1973	2		1					2		2						
1974	1							2								
1975	3	2+?						4	2+?							
1976				1							1					
1977	2							2								
Total	102	157?	2	6	?	1	4	127	198?	3	6	?	1	4	15	22+?

Two U.S. escape distance failures were Earth orbital successes. Soviet and Chinese failures are not reported, and the Soviet estimated figure merely assumes the same failure ratio as experienced by the United States, except that two failures were revealed by the U.S. Government, two were reported by the Soviet Government, and 20 more payloads reaching Earth orbit were known by their characteristics and timing to be escape mission failures.

III. TABLE OF SPACE "FIRSTS" -- U.S. AND SOVIET

Any attempt in simple form to compare the relative pace of the two principal space programs through a table of firsts has certain weaknesses, as it does not answer by how many days or years a particular event occurred in one country before another. Further, it does not distinguish between a nominal first accomplishment in crude form by one country, sometimes followed by a much more impressive and elaborate follow-up by the other country. Nonetheless, such firsts do affect public opinion, and analysis by various fields of endeavor may give some sense of relative direction of pacing efforts in each country. The table which follows attempts such a measure:

TABLE 2

Major Space "Firsts"

United States			Union of Soviet Socialist Republics		
Event	Satellite	Launch Date	Event	Satellite	Launch Date
Science			Science		
Van Allen radiation belts	Explorer 1	2/ 1/58	Orbiting geophysical lab	Sputnik 3	5/15/58
Earth shape measured	Vanguard 1	3/17/58	Farside lunar picture	Luna 3	10/ 4/59
Orbiting solar observatory	OSO 1	3/ 7/62	Cosmic ray measurements	Proton 1	7/16/65
Data from Venus	Mariner 2	8/27/62	Lunar surface pictures	Luna 9	1/31/66
Geodetic satellite	Anna 1B	10/31/62	Lunar surface bearing test	Luna 13	12/21/66
Lunar close-up pictures	Ranger 7	7/28/64	Venus atmospheric probe	Venera 4	6/12/67
Mars pictures	Mariner 4	11/28/64	Automated return of lunar sample	Luna 16	9/12/70
Micrometeorite satellite	Pegasus 1	2/16/65			
Lunar orbit pictures	Orbiter 1	8/10/66	Automated lunar roving laboratory	Luna 17	11/10/70
Lunar trenching	Surveyor 3	4/17/67			
Color picture of full Earth face	DODGE	7/ 1/67	Venus soil analysis	Venera 8	3/27/72
			Venus surface pictures	Venera 9	6/ 8/75
Lunar soil chemical analysis	Surveyor 5	9/ 8/67			
Point-stabilized Orbiting Astro-Observatory	OAO 2	12/ 7/68			
Live lunar TV broadcast	Apollo 8	12/21/68			
Return of lunar rocks	Apollo 11	7/16/69			
Long life lunar surface sensors	Apollo 12	11/14/69			
Color pictures of Jupiter	Pioneer 10	3/ 3/72			
Radiotelescope, far side Moon	Explorer 49	6/10/73			
Pictures of Venus	Mariner 10	11/ 3/73			
Pictures of Mercury	Mariner 10	11/ 3/73			
Solar probe	Helios 1	12/10/74			
Mars surface pictures	Viking 1	8/22/75			

TABLE 2 (continued)

Applications			Applications		
Active communications	Score	12/18/58	Domestic communications	Molniya 1-1	4/23/65
TV pictures from space	Explorer 6	8/ 7/59	Fractional orbit bombardment	Kosmos 139	1/25/67
Weather satellite	Tiros 1	4/ 1/60			
Navigation satellite	Transit 1B	4/13/60	Satellite inspector/ destructor	Kosmos 249	10/20/68
Missile detection	Midas 2	5/24/60			
Observation recoverable flight	Discoverer 13	8/10/60	Radar ocean surveillance	Kosmos 402?	4/ 1/71
Passive communications	Echo 1	8/12/60			
Nuclear explosion detection	Vela Hotel	10/17/63			
Earth resources satellite	ERTS 1	7/23/72			
Synchronous 24-hour weather	SMS 1	5/17/74			
Bio and Manned Flight			Bio and Manned Flight		
Manned orbital maneuver	Gemini 3	3/23/65	Biosatellite	Sputnik 2	11/ 3/57
Controlled extravehicular activity	Gemini 4	6/ 3/65	Recovery, orbited animals	Korabl Sputnik 2	8/19/60
Manned space rendezvous	Gemini 6,7	12/ 4/65	Recovery orbited man	Vostok 1	4/12/61
Manned docking	Gemini 8-Agena	3/16/66	Multi-manned spacecraft	Voskhod 1	10/12/64
Manned lunar orbit	Apollo 8	12/21/68	Extravehicular activity	Voskhod 2	3/18/65
Manned lunar return reentry	Apollo 8	12/21/68	Recovery, circumlunar live animals	Zond 5	9/21/68
Lunar orbit rendezvous	Apollo 10	5/18/69			
Lunar landing and return	Apollo 11	7/16/69	Transfer crew between ships	Soyuz 4-5	1/14-15/69
Lunar pinpoint landing	Apollo 12	11/14/69			
Manned lunar rover	Apollo 15	7/26/71	18-day flight	Soyuz 9	6/ 1/70
28-day flight	Skylab 2	5/25/73	Space station	Salyut 1	4/19/71
59.3-day flight	Skylab 3	7/28/73	23.75-day flight	Soyuz 11	6/ 6/71
84-day flight	Skylab 4	11/16/73	International docking	Soyuz 19	7/15/75
International docking	Apollo	7/15/75	2 Ferry craft docked to station	Soyuz 26-27	1/10/78

TABLE 2 (continued)

Space Flight and Propulsion			Space Flight and Propulsion		
Multiple spacecraft payload	Transit/ Solrad	6/22/60	Space flight	Sputnik 1	10/ 4/57
Payload recovery	Discoverer 13	8/10/60	Earth escape spacecraft	Luna 1	1/ 2/59
Synchronous satellite	Syncom 2	7/26/63	Lunar impact	Luna 2	9/12/59
Hydrogen rocket orbited	Centaur 2	11/27/63	Orbital platform launch	Sputnik 5	2/12/61
Docked spacecraft maneuver	Gemini 10-Agena	7/18/66	Venus flyby	Venera 1	2/12/61
			Mars flyby	Mars 1	11/ 2/62
Lunar-velocity reentry	Apollo 4	11/ 9/67	Venus impact	Venera 3	11/16/65
Constant deceleration reentry	Apollo 8	12/21/68	Lunar soft landing	Luna 9	1/31/66
			Lunar orbiter	Luna 10	3/31/66
Mars orbit	Mariner 9	5/30/71	Automatic docking	Kosmos 186/ 188	10/27-29/67
Jupiter flyby	Pioneer 10	3/ 3/72	Recovery, lunar payload	Zond 5	9/21/68
Solar system escape	Pioneer 10	3/ 3/72	Skip reentry lunar payload	Zond 6	11/10/68
Venus/Mercury flyby	Mariner 10	11/ 3/73			
Jupiter/Saturn flyby	Pioneer 11	4/ 5/73	Venus soft landing	Venera 7	7/17/70
			Mars impact	Mars 2	5/19/71
			Mars soft landing	Mars 3	5/28/71
			Venus orbit	Venera 9	6/18/75
Auxiliary Power Systems			Auxiliary Power Systems		
Solar cells	Vanguard 1	3/17/58	Battery power	Sputnik 1	10/ 4/57
Isotope power	Transit 4A	6/29/61			
Nuclear reactor in orbit	Snapshot 1	4/ 3/65			
Fuel cell	Gemini 5	8/21/65			

IV. SUPPORTING RESOURCES FOR SPACE FLIGHT

The ability of the two leading space powers to perform depends in the short run on the availability of existing resources to support such flights. These consist of finances, manpower, laboratories, factories, launch sites, tracking facilities, and launch vehicles. This section examines these categories to the extent data are available.

A. How much does each nation spend on space?

The United States by September 1978 expects to have spent $100 billion total since the beginning of the space program on space work in the several agencies of Government involved. These expenditures reached a peak of $7.7 billion in FY 1966, and in this fiscal year (1978) should be about $6.5 billion. Therefore, at the peak, we were spending close to one percent of gross national product, and today we are spending about 1/3 of one percent.

The Soviet Union does not publish space budget data. Because they fly a greater weight of hardware, one could assume that their program is at least of the same magnitude as that of the United States at its former peak, and may be larger. Their gross national product is thought to be about half that of the United States, and therefore they probably spend about two percent of their gross national product on space.

International comparisons of this nature are notoriously difficult to make, and one should avoid the temptation to convert such crude estimates into ruble or dollar equivalents.

B. How much manpower is engaged in space work?

In the United States, the National Aeronautics and Space Administration (NASA) program alone at its peak employed about 400,000 people (with 7 percent of these on the NASA payroll), but now has dropped to about 150,000. There were probably about 600,000 people at the peak employed in total U.S. space work. This figure does not include the indirect

beneficiaries of the space program from the multiplier effects of these expenditures, nor does this figure emphasize the dependence of some regions upon space expenditures.

The Soviet Union does not disclose how many people are employed in their space work. The productivity of this work force in comparison with that of the United States is now known, either. One would like to think our productivity is higher, but some Soviet approaches to space development may be simpler than ours, which incorporate very extensive testing and duplicative facilities in our industry. The Soviet work force may be close to 600,000 people because their effort today seems to be at least equal to our 1966 peak.

C. <u>How well equipped is each country in space laboratories and factories</u>?

The United States has several major NASA development centers, and other facilities operated by the Air Force and the Energy Research and Development Administration (ERDA). The private aerospace industry has a widespread industrial base capable of building and testing our hardware. However, the reduction of manpower at work in the space industry by more than one half has dispersed many of the trained teams needed to man these facilities, and any resumption of full scale efforts to utilize the physical plant could not come immediately.

The Soviet Union does not allow visits to its development facilities and no real measure of their total capacity is available in the public domain.

We are aware of the existence of many technical and scientific institutes, and have heard of a special space city in Kazakhstan (Leninsk?) where it is believed major assembly work is done. There is no reason to believe their total aerospace industry is as fully equipped as our own, because of their tendency to do more testing in flight compared with the United States. On the other hand, missiles of somewhat similar capabilities, but with different design philosophies appearing in Moscow parades, suggest the existence of more than one design and development team for space work just as in Soviet aviation.

D. How do the two countries compare in launch sites?

The United States has its major launch site for manned, lunar, planetary, and communications satellites at Cape Canaveral in Florida. It has a second important site for polar orbit military support flights and most weather and navigation launchings on the California coast at Vandenberg Air Force Base. A third minor site for small payloads is at Wallops Island, Virginia. Short-range vertical testing is done at White Sands, New Mexico.

The Soviet Union has developed launch sites amazingly like the United States pattern. Their major site for manned, lunar, planetary, and some communications satellites, plus other developmental work, is near Tyuratam and Leninsk in Kazakhstan. They call it the Baykonur Cosmodrome, but it is about 370 kilometers from the town of Baykonur. A second, largely military operational site, but also used for navigation, communication, and weather satellites, is near Plesetsk in the arctic north of Moscow. The third site is more modest, near Kapustin Yar on the Volga, south of what used to be Stalingrad (now Volgograd). It launches vertical probes as does White Sands, and small orbital payloads as does Wallops Island.

Each country seems to be adequately equipped with launch pads and ground support. Of course, as new vehicle systems come along, these require additional specialized facilities. The Soviet Union does not permit routine visits to its launch sites, and General de Gaulle with his personal physician (in 1966) and President Pompidou (in 1970) were the only known Westerners to have visited Tyuratam until 1975, when a few Americans had a limited glimpse of this base. Eastern European, Swedish, and Indian scientists have been allowed to attend launches of their payloads at Kapustin Yar or Plesetsk.

Table 3 summarizes the number of launch successes and resulting payloads from all sites of the world through 1977.

TABLE 3 -- Worldwide Summary of Successful Space Launches by Site 1957-1977

Place	Earth Orbit	Lunar or Escape	Total
Plesetsk, Russia	562		562
Tyuratam, Kazakhstan	397	49	446
Vandenberg AFB, California	402		402
Cape Canaveral, Florida	224	55	279
Kapustin Yar, Russia	66		66
Wallops Island, Virginia	16		16
Indian Ocean Platform, Kenya	8		8
Shuang Cheng-tzu, China	7		7
Uchinoura, Japan	7		7
Kourou, Guyane	6		6
Hammaguir, Algeria	4		4
Tanegashima, Japan	3		3
Woomera, Australia	2		2
Total	1,704	104	1,808

E. How well equipped is each country in tracking facilities?

As an outgrowth of the IGY period, the United States created a worldwide tracking system with the cooperation of many other countries. This has been upgraded to a much higher capacity to meet the needs of Apollo as well as other programs. For our deep space work, we have large 25.9- or 64-meter diameter dish antennas in California, Australia, and Spain which supported both the lunar portion of Apollo and distant planetary flights. Even with all these facilities, our system has had to be supplemented with tracking ships and special electronic-systems aircraft working in conjunction with satellites used to relay data on a real-time basis. Data relay satellites will perform more of these functions in the future.

The Soviet Union claims to have a nationwide tracking system, and the great spread of their country (about 2-1/2 times that of the United States) gives them a good systems start without leaving their own territory. There have been occasional press reports of Soviet efforts to put some tracking facilities into other countries such as

in Africa or in Cuba. Their principal deep space tracking facility is in the Crimea and has been visited by Sir Bernard Lovell of the United Kingdom who heads the Jodrell Bank radio telescope facility.

Primarily, the Soviet Union accepts certain constraints to their space operations, and relies on ships to fill in gaps. Eleven ships have been named as assigned to the Soviet Academy of Sciences for space work, and often these are described as scattered around the world for space support purposes. Other tracking ships, not identified as under Academy control, have been pictured in the press and seem to be associated primarily with military missile tests, but could support space work as well. The most impressive tracking ship was the Kosmonavt Vladimir Komarov, used for lunar support work in the tropical waters of the Western Atlantic Ocean. It is frequently in Havana harbor. Now it is outclassed by the larger Akademik Sergey Korolev and much larger, Kosmonavt Yuriy Gagarin. For support of manned flights, one ship typically anchors off Nova Scotia. Soviet Molniya satellites relay information between tracking ships and the U.S.S.R. The principle of launch constraints is to make flights only at times and places which will be in view of Soviet tracking stations at critical periods during the flight, and at other times to do without tracking, storing on tape in the space craft some data for later replay. The Kosmonavt Volkov, first of four new tracking ships entered service in 1977.

F. How do the two countries compare in launch vehicles?

The United States has used launch vehicles scaled to lift payloads from as light as nine kilograms up to the Saturn V which could carry over 136,000 kilograms to low Earth orbit. In its manned programs, the Mercury spaceship weighing about 1,360 kilograms was launched to orbit by Atlas. The Gemini weighing about 3,630 kilograms was launched by Titan II. The first manned Apollo flight was about 20,410 kilograms, put up by Saturn I B. The lunar version Apollos, launched by Saturn V, were about 52,600 kilograms in the vicinity of the Moon. (For any launch vehicle, the farther the orbit

is from the Earth, the greater the velocity required to get there and the smaller the payload. This is why Saturn V carries much less to the Moon than to Earth orbit.)

The Soviet Union started to use in 1957 its original ICBM, with an orbital lift capacity of 1,360 kilograms. The same basic (A) vehicle is in use today with upper stages added to improve performance. These upper stages permitted the launch of about 450 kilograms to the Moon in the first Luna series, and about 1,500 kilograms in the second Luna series. The early Luna-type launch rocket also was able to put up Vostok manned craft of 4,700 kilograms. The weight of Soyuz is about 6,575 kilograms still using this same basic launch vehicle with improved staging. Their Proton (D) launch vehicle has been demonstrated to carry 20,000 kilograms to Earth orbit. Its circumlunar capacity should be on the order of 4,820 kilograms; and used to Mars, it carried 4,650 kilograms. We have not yet seen the very large Soviet (G) vehicle confidently predicted by NASA officials over the last decade. Lesser Soviet launch vehicles (B, C, and F) account for other unmanned programs.

Table 4 summarizes world-wide use of basic vehicles for successful launches to Earth orbit and beyond, through 1976.

TABLE 4 -- Number of Successful Launches to Earth Orbit and Beyond by Basic First Stage, 1957-1977

Name	Nationality	Vehicle Origin	Number
Sapwood (A)	USSR	missile (SS-6)	648
Thor	USA	missile	337
Skean (C)	USSR	missile (SS-5)	171
Atlas	USA	missile	152
Sandal (B)	USSR	missile (SS-4)	144
Titan	USA	missile	111
Scout	USA		67
Scarp (F)	USSR	missile ((SS-9)	59
Proton (D)	USSR		50
Saturn 5	USA		13
Saturn 1	USA		13
Diamant B	France		6
Mu	Japan		6
China B	China	missile (CSS-X4)	5
Redstone	USA	missile	4
Jupiter	USA	missile	4
Diamant	France		4
Vanguard	USA		3
Unspecified	USSR		3
"N"	Japan	missile (Thor)	3
China A	China	missile (CSS-2)	2
Lambda	Japan		1
Black Arrow	U.K.		1
Total			1,807

G. Why did the Soviet Union originally have a lead in propulsion?

It is argued in the Western World that the Soviet Union sized their first ICBM before the thermonuclear breakthrough in weaponry allowing light weight hydrogen bomb warheads. Hence, it ended up with a large and uneconomic vehicle on its hands, while the United States was able to scale down the design size of Atlas and Titan missiles because of reductions in warhead weight. Whether this assessment is right or not, the consequence has been helpful to the Soviet space program. While the United States was building its IGY program around a 9-kilogram Vanguard, they were building a 1,327-kilogram Sputnik 3, and planning to do even more on lunar flights.

Until the Saturn family appeared in service, at each stage the Soviet Union was equipped with larger launch vehicles by far. The repetitive use of the standard

(A) vehicle probably gave it good reliability. It is rugged, has a first stage of five sets of tanks, four of which fall away from the core vehicle early in flight. Each of the five segments has four rocket nozzles, plus separate steering nozzles.

By Soviet account, several of their launch vehicles use liquid oxygen and a kerosene derivative for the first stages (as do many of those of the United States), and use fairly conventional storable fuels for upper stages. There is no sign of a secret breakthrough in fuels, but their engines are run at a relatively high pressure, increasing efficiency.

The United States has developed solid-fuel rockets mostly for military missile purposes, and certain space upper stages. The small Scout rocket is solid fuel in all stages, and strap-on boosters of solid fuel are used with Titan IIIC, D, & E, and Augmented Thrust Thors.

The Soviet Union began to put large solid rocket missiles into its Moscow parades only in the last ten years or so, well behind use of such rockets in the United States. These have some missile use, but there is no clear sign that solid-fuel rockets have been used for Soviet space purposes.

The United States experimented with components for a nuclear rocket as an upper stage for Saturn. A solid core reactor would heat hydrogen to be expelled from the nozzle. Despite this long time development effort, the work has now been cancelled as an economy move.

The Soviet Union could be developing a nuclear rocket, but so little has been said to date by them in this regard that any opinion on the subject would be highly speculative.

The Russians have issued publicity on electric rockets, but there is no sign this work has gone much beyond early proof-of-principle, and for orientation of vehicles in a few cases.

So, for the present, looking at the upper range of national capabilities, the Saturn V clearly has been the best operational weight lifter in the world. If the NASA officials are right, the 3.4 million-kilogram-thrust Saturn V may be challenged by a Soviet vehicle in the 4.5 to 6.4 million-kilogram-thrust class. It would not necessarily be as much larger in payload capacity as the figures imply because Saturn V uses liquid hydrogen for fuel in its upper stages, and there is no firm evidence the Soviet Union has switched to high energy fuel, although such a switch could come during the 1970's.

V. MANNED FLIGHT COMPARISONS

The brief history already reported touched on the changing nature of the "race" between the two space powers. Through Voskhod, every advantage remained with the Soviet Union. During Gemini, one "first" after another came to the United States along with a strong lead in total orbital experience. Apollo moved more rapidly than any Soviet corresponding effort, especially because at this time a Soviet launch vehicle capable of supporting a manned lunar landing had not orbited. But the Soyuz family of manned craft, with two compartments for men, may prove able to serve usefully as ferries to orbit, as components in elementary space stations, and possibly even as part of a future lunar landing system. Discussions of U.S.-Soviet comparisons frequently bring questions, of which several can be posed:

A. How true are stories of cosmonaut deaths?

Although there is always the possibility of an accident close to the launch pad of which we would have no knowledge, the odds are overwhelming that the only Soviet cosmonauts killed in space flight so far are Komarov in 1967, and Dobrovolskiy, Volkov, and Patseyev in 1971. This is because the Russians have followed a conservative approach to manned flight with heavy vehicles allowing much redundancy in equipment. Manned flights have been preceded by unmanned tests in the same pattern. Flights are supported by world-wide dispositions of tracking and rescue ships. Private word to other nations has been passed in Moscow before flights. Live television of the men in orbit has been the general rule.

With all this care and its known pattern of success, we are asked by those who believe many Russians have died in orbit in effect to accept the existence of a second Soviet manned flight program run with reckless abandon which always kills the flight crews. These purported failure flights, often detailed irresponsibly in the press with names and dates to make the unproven data look convincing, apparently would be

conducted without advance warning, without tracking ships, without television, and use different models of larger, untried ships which always kill their crews or leave them stranded in orbit. Yet the "flights" cannot be detected by the same U.S. tracking systems that usually find even chance pieces of space debris at the altitudes manned flights occur. This is hardly credible.

B. Do the Russians fake their flights?

In general, the Soviet Union seems to find that real successes which can be tracked and monitored by the Western World are more effective propaganda than inventing unreal flights which might fool the public briefly but would not impress governments with tracking facilities.

The Russians do not give many details in advance of their flights, so that when successes are less than complete they have less to explain away. They usually claim that all mission objectives have been met when in fact this may not be the case; but in the absence of a preflight statement, it would be hard to disprove what they say.

One area in which they were especially subject to attack for faking related to the space walk by Leonov. Some specialists thought the pictures released had been simulated or doctored. Actually, in a number of cases, a review of the original Soviet film shows it used such language as "Here is a simulation . . . ," and this description somehow had been overlooked by the time other people in the Western World examined the questionable film, and quite correctly found some portions of it were not the real thing. Simulations were used where no camera could be positioned to capture the real event as it happened.

C. How do the publicity policies of the two countries compare?

The NASA (civilian) part of the U.S. program is generally run on a very open basis with the press at launches and most questions about flights answered both before they occur and after they are over. There is less openness in the Department of Defense

space launchings, most of which are not given names or purpose, advance notice, or published results.

The Soviet Union holds to a minimum advance notice of flights, limits information on the bulk of their flights, but at least makes a prompt announcement, assigns a name, and gives orbital parameters for all flights which are successful in reaching some kind of an orbit which looks reasonable. All are described as scientific in purpose and successful in some degree. While a reporter in the United States can query NASA for more details of NASA flights, reporters rarely are able to gain elucidating details through questioning Soviet officials about their flights.

D. Accomplishments of manned flights

Apollo and Skylab have given the United States a proven capacity to stay in orbit with multiple-man crews up to 84 days, to adjust orbits repeatedly, to rendezvous successfully by several means, to dock and transfer crews, and to stay for hours outside the spaceship in protective suits. The men on occasion have felt discomfort, but have been able to perform basic tasks. NASA began flights with a reduced-pressure pure oxygen breathing systems. It has made occasional use of television from the spaceship to Earth, and by the time of Apollo 15 had reached a high level of perfection in color pictures even from a roving vehicle on the Moon. With these craft phased out, the United States has given up any manned capacity until the new space shuttle enters service.

Soyuz and Salyut have extended the Soviet manned capabilities as well. Soyuz is said to be capable of flying up to 1,300 kilometers altitude, and to provide a stay time of 30 days. So far, no Soviet ship with men on board has flown that high, although unoccupied ships have made circumlunar flights. Maximum stay time has been 63 days with Salyut 4. But the Russians have demonstrated both a fully automatic and partly manual rendezvous and docking capability, and have transferred a crew in orbit from one ship

to another. They have consistently used an atmosphere equivalent to normal air at sea-level pressure, and have used television from orbit extensively since their first manned flight.

E. Summary table of manned flights

The table which follows gives the principal results and characteristics of each U.S. and Soviet manned flight to date:

TABLE 5

Summary List of Manned Space Flights

Launch Date	Vehicle Name	Crew	Weight (kgs.)	Duration (hrs.,min)	Orbits	Highest Altitude (kms.)	National Cumulative Manhours
1961							
Apr. 12	Vostok 1	Gagarin	4,725	1:48	1	327	1:48
May 5	MR-3	Shepard	1,290	:15	--	188	:15
July 21	MR-4	Grissom	1,286	:16	--	190	:16
Aug. 6	Vostok 2	Titov	4,731	25:18	17	257	27:06
1962							
Feb. 20	MA-6	Glenn	1,355	4:55	3	261	5:26
May 24	MA-7	Carpenter	1,349	4:56	3	269	10:22
Aug. 11	Vostok 3	Nikolayev	4,722	94:22	64	251	121:28
Aug. 12	Vostok 4	Popovich	4,728	70:57	48	254	192:25
Oct. 3	MA-8	Schirra	1,373	9:13	6	283	19:35
1963							
May 15	MA-9	Cooper	1,376	34:20	23	267	53:55
Jun. 14	Vostok 5	Bykovskiy	4,720	119:06	81	222	311:31
Jun. 16	Vostok 6	Tereshkova	4,713	70:50	48	233	382:21
1964							
Oct. 12	Voskhod 1	Komarov					
		Yegorov					
		Feoktistov	5,320	24:17	16	409	455:12
1965							
Mar. 18	Voskhod 2	Belyayev					
		Leonov	5,682	26:02	17	490	507:16
Mar. 23	GT-3	Grissom (2)					
		Young	3,225	4:53	3	224	63:41
Jun. 3	GT-4	McDivitt					
		White	3,574	97:56	66	296	259:33
Aug. 21	GT-5	Cooper (2)					
		Conrad	3,605	190:55	128	346	641:23
Dec. 4	GT-7	Borman					
		Lovell	3,663	330:35	220	327	1,302:33
Dec. 15	GT-6	Schirra (2)					
		Stafford	3,546	25:51	17	304	1,354:15

TABLE 5 (continued)

1966							
Mar. 16	GT-8	Armstrong					
		Scott	3,788	10:41	7	298	1,375:37
Jun. 6	GT-9	Stafford (2)					1,520:19
		Cernan	3,750	72:21	47	330	1,520:19
July 18	GT-10	Young (2)					
		Collins	3,741	70:47	46	766	1,661:53
Sept.12	GT-11	Conrad (2)					
		Gordon	3,860	71:17	47	1,369	1,804:27
Nov. 11	GT-12	Lovell (2)					
		Aldrin	3,763	94:35	63	302	1,993:37
1967							
Jan. 27	AS-204	Grissom (3)1/		[Not a space flight, but date of fatal fire on pad during test preliminary to later scheduled flight.]			
		White (3) 1/					
		Chaffee 1/	20,412				
Apr. 23	Soyuz 1	Komarov (2) 1/	6,450	26:37	18	224	533:53
1968							
Oct. 11	Apollo 7	Schirra (3)					
		Eisele					
		Cunningham	20,569	260:09	174	449	2,774:04
Oct. 26	Soyuz 3	Beregovoy	6,575	94:51	64	252	628:44
Dec. 21	Apollo 8	Borman (2)					
		Lovell (3)					
		Anders	43,663	147:01	2(Earth)		
					10(Moon)	400,000	3,215:07
1969							
Jan. 14	Soyuz 4	Shatalov					
		(Yeliseyev)					
		(Khrunov)	6,625	71:23	48	253	795:45
Jan. 15	Soyuz 5	Volynov					
		Yeliseyev					
		Khrunov	6,585	72:56	49	253	868:41
Mar. 3	Apollo 9	McDivitt (2)					
		Scott (2)					
		Schweickart	43,185	241:01	162	504	3,938:10

1/ Fatality

TABLE 5 (continued)

May 18	Apollo 10	Stafford (3) Young (3) Cernan (2)	48,638	192:03	2(Earth) 31(Moon)	400,000	4,514:19
Jul 16	Apollo 11	Armstrong (2) Collins (2) Aldrin (2)	49,698	195:19	2(Earth) 30(Moon)	400,000	5,100:16
Oct. 11	Soyuz 6	Shonin Kubasov	6,577	118:42	80	230	1,106:05
Oct. 12	Soyuz 7	Filipchenko Gorbatko Volkov	6,570	118:41	80	226	1,462:08
Oct. 13	Soyuz 8	Shatalov (2) Yeliseyev (2)	6,646	118:50	80	256	1,699:48
Nov. 14	Apollo 12	Conrad (3) Gordon (2) Bean	49,804	244:36	2(Earth) 45(Moon)	400,000	5834:04
1970 Apr. 11	Apollo 13	Lovell (4) Haise Swigert	49,990	142:55	2(Earth) 1(Moon)	400,000	6,262:49
Jun. 1	Soyuz 9	Nikolayev (2) Sevastyanov	6,500	424:59	286	267	2,549:46
1971 Jan. 31	Apollo 14	Shepard (2) Roosa Mitchell	46,347	216:02	2(Earth) 34(Moon)	400,000	6,910:55
Apr. 19	Salyut	(Occupied by Soyuz 11 crew)	18,600?	---	---	282	---
Apr. 22	Soyuz 10	Shatalov (3) Yeliseyev (3) Rukavishnikov	6,565?	47:46	32	246	2,693:04
Jun. 6	Soyuz 11	Dobrovolskiy 1/ Volkov (2) 1/ Patsayev 1/	6,575?	570:22	385	282	4,404:10

1/ Fatality

TABLE 5 (continued)

July 26	Apollo 15	Scott (3) Irwin Worden	52,759	295:12	2(Earth) 74(Moon)	400,000	7,796:31
1972 Apr. 16	Apollo 16	Young (4) Duke Mattingly	51,571	265:51	2(Earth) 65(Moon)	400,000	8,594:04
Dec. 7	Apollo 17	Cernan (3) Schmitt Evans	51,808	301:52	3(Earth) 75(Moon)	400,000	9,499:40
1973 May 14	Skylab 1	(Occupied by successive crews)	89,439	---	---	440	---
May 25	Skylab 2	Conrad (4) Kerwin Weitz	30,803	672:50	433	440	11,518:10
Jul. 28	Skylab 3	Bean (3) Garriott Lousma	30,694	1,427:09	919	440	15,799:37
Sep. 27	Soyuz 12	Lazarev Makarov	6,575?	47:16	32	345	4,498:42
Nov. 16	Skylab 4	Carr Gibson Pogue	31,232	2,017:16	1,298	442	21,851:25
Dec. 18	Soyuz 13	Klimuk Lebedev	6,575?	188:55	127	273	4,876:32

TABLE 5 (continued)

1974							
June 24	Salyut 3	(Occupied by Soyuz 14 crew)	18,900?	---	---	276	---
July 3	Soyuz 14	Popovich (2) Artyukhin	6,570	337:30	252	277	5,631:32
Aug. 25	Soyuz 15	Sarafanov Demin	6,570?	48:12	32	275	5,727:56
Dec. 2	Soyuz 16	Filipchenko (2) Rukavishnikov (2)	6,570?	142:24	96	225	6,012:44
Dec. 26	Salyut 4	(Occupied by Soyuz 17, 18 crews)	18,900?	---	---	361	---
1975							
Jan. 10	Soyuz 17	Gubarev Grechko	6,570	709:20	466	361	7,431:24
Apr. 5	Anomaly	Lazarev (2) Makarov (2)	6,570?	:20	---	---	7,432:04
May 24	Soyuz 18	Klimuk (2) Sevastyanov (2)	6,570?	1,511:20	993	384	10,454:44
July 15	Soyuz 19	Leonov (2) Kubasov (2)	6,800	142:31	96	225	10,739:46
July 15	Apollo	Stafford (4) Slayton Brand	14,743	217:28	145	225	22,503:49

TABLE 5 (continued)

1976 June 22	Salyut 5	(Occupied by Soyuz 21, 24 crews)	18,900?	---	---		---
July 6	Soyuz 21	Volynov (2) Zholobov	6,570?	1,182:24	790	281	13,104:34
Sep. 15	Soyuz 22	Bykovskiy (2) Aksenov	6,570?	189:54	127	280	13,484:22
Oct. 14	Soyuz 23	Zudov Rozhdestvenskiy	6,570?	48:06	32	275	13,580:34
1977 Feb. 7	Soyuz 24	Gorbatko (2) Glazkov	6,570?	425:23	285	281	14,431:20
Sep. 29	Salyut 6	(Occupied by Soyuz 26, 27 crews)	18,900?	---	---		---
Oct. 9	Soyuz 25	Kovalenok Ryumin	6,570?	48:46	32	353	14,528:52
Dec. 10	Soyuz 26	Romanenko Grechko (2)	6,570?				
1978 Jan. 10	Soyuz 27	Dzhanibekov Makarov (3)	6,570?				

VI. MILITARY VS. CIVILIAN SPACE ACTIVITIES

Questions are frequently raised as to the differences of purpose, organization, and use of space programs in the Soviet Union and the United States. The most frequently asked questions are posed here with tentative answers:

A. How do the two programs compare in purpose: is one more military than the other?

For the most part there seems to be little difference between the Soviet and U.S. space programs as to general purpose and direction (with two major exceptions to be noted later). Both are broadly based, with elements of scientific exploration, technology development, national image building, practical applications, and military support services. About 57% of U.S. flights are conducted for the Department of Defense, with 50% for strictly military purposes. About 68% of Soviet flights are for strictly military purposes. About 42% of current U.S. space funds are spent for the programs of DOD which are less expensive than those of NASA because more of them are for routine operations rather than new development. Corresponding breakdowns for the Soviet total program are harder to establish because of their secrecy of budget data, and their claim that all flights are scientific. Yet a very considerable number of their flights and research give convincing indications of serving military purposes.

B. How do the two countries manage their space programs?

Under the terms of the National Aeronautics and Space Act of 1958, the principal portion of the U.S. space program is run by a civilian organization, the National Aeronautics and Space Administration. But another major segment is operated by the Department of Defense using the Air Force as its executive agent, with emphasis on supplying military support, or doing the R&D associated with military support. Lesser amounts of the program are scattered among other development or user agencies such as ERDA (development), the Departments of Commerce, Transportation, Agriculture and

Interior (users). A coordinating body, which operated from 1958 to 1973, the National Aeronautics and Space Council, has been disestablished.

Much less is known about the Soviet pattern of organization. The Russians have held secret even the names of their top space officials with very few exceptions. Nor is the exact names of their space organization known. The Soviet Academy of Sciences plays a role in planning a part of the program. The Soviet Strategic Rocket Forces conduct launches and apparently are responsible for supplying the launch vehicles. But the interfaces are obscure, and if there are construction and testing ministries in between, little is know of them.

C. Do military flights constitute a threat to the world?

It is United States policy that our military flights are nonaggressive. Many of our flights are hardly distinguishable from flights conducted for civilian application purposes. Thus a message sent by satellite, or a weather report from space observation, or navigational data to a ship are technically neutral in character. Often these services are of a traditional nature, simply done more speedily or cheaply by space means. Whether such services are aggressive is in the mind of the user, and are not subject to scientific, absolute determination. In a philosophical sense, a businessman or a government civil department sending a message by satellite might be more "aggressive" than a military user sending data on personnel counts or number of wool socks in a warehouse somewhere.

Although the U.S. Government is reluctant to discuss the subject, careful observers of military space activities have a strong conviction that the most active development of military space flights lies in the area of Earth observation. President Johnson, speaking in Nashville, Tennessee on March 15, 1967, claimed in an "off-the-record" statement widely reported at the time that the dividends of military space operations to the United States were equal to ten times everything which had been spent on space. This

implied savings in our defense budget over a ten year period on the order of $400 billion, because of more precise information about military and related activities all over the world. American analysts argue that sure information from space is one of the greatest safeguards against miscalculation by the major powers, and hence, in the absence of explicit international agreements for open skies and ground inspection, is the best bargain all countries of the world have to limit the arms race and to provide insurance against a general holocaust of thermonuclear weapons.

There is no doubt that the Soviet Union has a large and regular program of military support flights, including use of satellites for photographic observation, electronic listening, weather reporting, communications relaying, and ship navigation. Although these space services undoubtedly enhance Soviet military capabilities, in net balance they probably are to the advantage of the United States if surer knowledge between these two big power makes each more cautious and less prone to error in estimates.

D. What about space weapons -- is there a threat?

Ever since the days of Sputnik 1, there has been public worry about bombs dropped from orbit. The potential threat is there, but it must be qualified by many practical considerations. At the present time, the disadvantages of space weapons are sufficiently great that the United States has chosen not to develop them, and found little difficulty in agreeing to a treaty to ban weapons of mass destruction from orbit and all military activities from other celestial bodies.

The Soviet Union is also a party to this same treaty, and all reasonable analyses are fairly convincing that up to this time the Soviet Union has not placed nuclear bombs in orbit. Some of the logic runs as follows:

A bomb in orbit must be called down by signal, and on a particular orbit will fall close only to a selected path defined by the orbit, so that hitting a planned target is possible only at certain hours or days, and in a sudden emergency might not be near a useful target.

A bomb in orbit may be subject to malfunction because Soviet spacecraft have been notoriously short-lived in their reliability. A malfunctioning bomb might fall to destroy a Soviet city as well as one in an enemy country.

A bomb in orbit is less manageable than one in a silo at home or in a submarine, not only for reasons of maintenance, but also for command and control. If placed in orbit, it might be subject to spurious signals; and eventually the nuclear material might be wasted if the bomb ceased its functions, or the orbit decayed to let it fall at random, even with a safeguard against detonation.

A bomb in orbit can be precisely located, and hence intercepted by another space power.

One or a few bombs might be placed in orbit secretly or in disguised form, but having only a few would not be decisive against a second strike capability by the target country. If done for terror purposes with publicity, then the Soviet Union would not only be avowedly breaking the space weapons treaty but would risk a preemptive strike by the United States if the threat were believed.

On the other hand, if a larger and possibly useful number of weapons were placed in orbit, the fact of such launches would quickly become evident to the radars, computers, and analysts in the United States, and the threat would be clear and require as positive a counter move as would a direct ICBM attack on this country. Such launchings would signal Soviet intentions with more warning time than would a surprise attack directly by ICBM's.

E. The fractional orbit bombardment system -- FOBS

In one respect the Soviet Union has already heightened tensions by testing a fractional orbit bombardment system. This is not a technical violation of the treaty because there is no reason to suppose they would need to carry nuclear material on board the test flights, and the dummy warhead has flown less than one full orbit. The pattern

has been to launch a satellite from the Soviet Union on a path avoiding the United States, and calling down the test warhead just before the end of the first orbit onto Soviet territory, while some minor debris and expended rocket casing stay in orbit for a few more hours before decaying.

From a Soviet point of view, FOBS has the advantage of complicating U.S. defenses. Although scientifically speaking the warhead is in orbit, in effect it is like an extended range ICBM capable of flying the long way around the world to bypass the normal ballistic missile early warning system (BMEWS) radar fences which point to the north. If flown by the usual shortest routes to the United States, it could do so with a depressed apogee compared with conventional ICBM's, so as to cut warning time to BMEWS because of the delayed detection brought by the curvature of the Earth hiding the presence of the low-flying warhead. But such flights in combat have disadvantages, too, including reduced accuracy on target if coming the long way around, and reduced payload by any route compared with the use of the same launch vehicle as an ICBM. The United States does not have a FOBS program because it does not regard them as necessary or desirable. The Russians obviously do, for reasons not wholly clear. However, there have been no flights since 1971.

F. A possible satellite inspector/destructor vehicle

A few years ago, the President announced the United States had at least a limited capability to intercept hostile satellites using missile systems based at Johnston and Kwajalein Islands in the Pacific. These would not have met all possible needs, but over the course of some days could have intercepted most satellites in sustained low orbit. These facilities are believed to have been shut down. The United States also once had a satellite orbital inspector program called Saint, which was abandoned before the first flight.

It is assumed that because the Soviet Union has a limited deployment of the Galosh ABM system, it probably also could intercept hostile satellites in about the same degree as the United States could have from its mid-Pacific installations.

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Additionally, the Soviet Union within its Kosmos series has flown satellites which British observers suspect from their orbital characteristics are launched by the same SS-9 Scarp (F) vehicle also used for the Soviet FOBS. These flights usually are maneuvered in orbit, and in both 1968 and 1970, two successive flights made a reasonably close intercept of a target satellite and then were in turn exploded into many pieces of debris. Three single intercepts were flown in 1971. In the absence of Soviet announcements, an assessment cannot be conclusive, but the suspicion remains that a capability to inspect and destroy satellites has been created. Flights resumed in 1976 using three target satellites and four interceptors. In 1977 there were also three target satellites and four interceptors.

G. Ocean surveillance

Still another part of the Soviet maneuverable satellite program using the F launch vehicle has been identified by DOD and by a British analyst as probably used for ocean surveillance by active radar able to penetrate clouds and darkness. If these judgments are correct, the main missions end some weeks after launch by separating the craft into several parts with one segment fired to a long life in higher orbit, perhaps because of a nuclear power source contained in it.

A second category of ocean surveillance flights stays at a higher altitude and is not maneuvered upwards later. Speculation is that these are electronic ferrets.

H. Mutual non-interference

For the time being at least, it remains in the Soviet interest not to interfere actively with U.S. satellite flights just as it is U.S. policy not to interfere with theirs. The SALT I agreement included a provision for non-interference with "national technical means" for policing compliance. The first visible new threat to such reciprocity was the report of late 1975 that the Russians had begun probing U.S. military satellites with powerful laser beams. If true, this could lead to very destablizing relations in space. A follow-up Department of Defense analysis was that gas pipeline fires accounted for the phenomean of temporary saturation of our sensors. If correct,

that may be reassuring, although technologically the laser threat may be possible, and one hates to have in doubt any question of signal interpretation.

I. Summary table of military vs. civilian space flights

The table which follows attempts to divide as meaningfully as possible, though still tentatively, the space flights of the two nations as to whether they are civilian or military in character:

TABLE 6

Approximate Comparison of United States and Soviet Successful Space Launchings -- Primarily Civil Oriented Versus Presumptively Military Oriented

	Primarily or Ostensibly Civil				Presumptively Specialized Military	
Year	NASA	DOD	U.S. Total	USSR	DOD	USSR
1957	0	0	0	2	0	0
1958	0	5	5	1	0	0
1959	5	0	5	3	5	0
1960	5	1	6	3	10	0
1961	10	0	10	6	19	0
1962	18	1	19	15	33	5
1963	10	2	12	9	26	8
1964	22	2	24	13	33	17
1965	23	7	30	19	33	29
1966	30	9	39	16	34	28
1967	25	6	31	20	26	46
1968	19	4	23	22	22	52
1969	21	3	24	17	16	53
1970	12	1	13	26	16	55
1971	14	4	18	21	13	62
1972	17	1	18	19	13	55
1973	12	1	13	27	10	59
1974	14	0	14	26	8	55
1975	18	1	19	27	9	62
1976	13	1	14	24	12	75
1977	13	1	14	24	10	
Total	301	50	351	340	348	735

To a degree, classification has been arbitrary, following the detailed criteria set for in the report "Soviet Space Programs -- 1966-70" issued in January 1972 by the Senate Committee on Aeronautical and Space Sciences, (Sen Doc. 92-51).

VII. SPACE APPLICATION FLIGHTS

In the area of space applications, the United States has held a clear lead from the earlier days of the space program, and this experience has permitted us to move ahead to more advanced systems while the Soviet Union was still working hard to catch up.

A. Communications

The United States experimented with both civilian and military communication satellites, first with low-altitude pickup, tape storage, and replay systems, and also with passive reflectors of the balloon type. But now the pattern is well set to use satellites of increasing capacity each year, synchronous at about 35,880 kilometers which to all intents and purposes stay at a fixed point over the Equator relative to the ground. Color TV can be relayed across oceans, and telephone capacity is growing rapidly, with a matching drop in costs of operation.

The Soviet Union has gone quite a different path. Following by some years the U.S. start, since 1965 they have put up a series of Molniya 1 satellites which are heavier than corresponding U.S. communications satellites. These Molniya 1's fly in an orbit inclined at 63 degrees to the Equator with a low point over the southern hemisphere, but a long linger time at the peak of the orbit in the northern hemisphere, so that each is in view of major Soviet ground terminals for about eight hours a day, including those at near polar latitudes, harder to reach with our equatorial systems. Their high power has permitted the establishment of relatively low-cost terminals to distribute TV programs from Moscow to outlying points, as well as carrying telephone and computer data traffic. By proper spacing of four of these satellites in 12-hour semisynchronous orbits in orbital planes 90 degrees apart, it is possible to give full daily coverage, with each satellite traveling the same ground trace each day.

Now the Molniya l's have been relegated to military service with 8 operating the system and newer Molniya 2 and Molniya 3 satellites (4 each) using higher frequencies provide the prime service, arranged in the same planes as their earlier counterparts. In 1974 for the first time the Russians put Kosmos 637 and then Molniya 1S-1 into 24-hour synchronous equatorial orbits. Late in 1975 the Statsionar plan of 24-hour synchronous satellites, was announced as expanding to eleven expected over the next five years. Raduga, the first Statsionar, was launched December 22, 1975. It has been followed in 1976 by Raduga 2 and Ekran, a television distribution satellite. In 1977, Raduga 3 and Ekran 2 were also placed in orbit.

Military communications systems within the Kosmos program also are in place for theater tactical use and in store-dump mode worldwide. (Store-dump satellites receive messages, placing these on tape and replay them later on command.)

B. Weather reporting

The United States has an operational weather satellite system using the TIROS and ESSA (now NOAA) series, and gross world coverage is fairly good, including the ability of local stations to read the APT (automatic picture transmission) equipment on board many of these satellites for a "real time" view of local regional weather. More advanced sensors have been tested in the Nimbus and ATS (Advanced Technology Satellites) and the most recent NOAA series of flights. There are also military weather satellites in orbit. Even newer are 24-hour synchronous SMS and GOES satellites which individually can give continuous views of large areas.

Again, the Soviet Union came late to this field compared with the United States. Only since 1966 have they distributed satellite-gathered weather pictures, and these spacecraft have had the disadvantage of a shorter useful life before electronic failure, compared to United States spacecraft. Their pictures have a higher resolution which may give more detail, but which also reduces the amount of daily coverage a satellite can give, with many smaller area pictures having to be fitted together for

larger area views. On the other hand, the Soviet satellites more nearly resemble our advanced Nimbus craft in terms of the wider variety of sensors carried and the experimental work underway which may open up new discoveries. In 1977, for the first first time, a Soviet weather satellite was put into a retrograde, Sun-synchronous orbit (to take pictures at a constant local time), the pattern long favored for U.S. U.S. weather satellites. In addition to these Meteor weather satellites of lower altitude flights, weather cameras have been carried on some of the higher flying Molniya 1 satellites as well, so that a steerable camera at 40,600 kilometers can give wide area views like those taken by the U.S. craft at similar altitudes. Now the Russians are also getting ready to add a 24-hour synchronous weather satellite to the cooperative world system being created with the United States, Japan and Western Europe, but the flight has been delayed beyond 1977.

C. Navigation and traffic control

The United States has a U.S. Navy operational navigation satellite system, originally called Transit, now renamed NNSS. It operates through the passive reading on ships of Doppler shift in harmonic signals from the satellites, and the data are manipulated by a computer on board the ship in connection with broadcast data on the position of the satellite. It is not particularly suited to commercial economics, but it is highly effective for naval purposes. Commercial ships are now permitted to use the same system if they care to invest in the necessary computer equipment. Future civilian systems are more likely to require the ship or aircraft to play an active role by broadcasting signals to satellites, which will relay to a shore-based computer these data to find the ship or aircraft position, and this may serve in future traffic control systems as well. This has been tested in the ATS satellites.

The Soviet Union claims to have operational navigation satellite system, but the Russians have never identified the particular satellites used. However, certain of their Kosmos missions are flown in ways which strongly suggest these are navigation

satellites, probably linked with a passive ship system for naval purposes, which would seem a close parallel to the Transit system of the United States, even to using the same radio frequencies. Judgments as to quality are not possible in the absence of Soviet openness.

D. Geodesy and mapping

The United States has flown many geodetic flights in the interest of tying together maps of different parts of the world and for basic scientific studies to understand better the true shape of the world. If there have been mapping flights as well, the results have not been published.

The Soviet Union professes an interest in both geodesy and mapping, but too few findings have been made available to judge how far along they are in comparison with the United States. Some known Kosmos flights have the right characteristics to support such missions.

E. Earth resources

One of the most exciting new fields of space application is that of finding and managing Earth resources in many fields through use of satellites. It is expected that mineral deposits and oil fields can be found, forest fires located. Diseases of trees and agricultural crops may be identified as to location, censuses of crops taken, snow fall and water status reported, fisheries run more efficiently, and many other similar practical things done from space. The United States has now flown Landsat 1 and 2 (previously known as ERTS 1 and 2) to conduct such experiments.

The Soviet Union has expressed a similar interest. Recent Soyuz flights and the Salyut stations were announced as having explored data-gathering techniques for Earth resources purposes. During 1977, two short-life recoverable Kosmos flights were specifically identified as doing Earth-resources work.

F. Summary table of space mission by category

The table which follows is somewhat arbitrary in classification, but attempts to place in broad mission category each payload launched since 1957 by the United States and the Soviet Union. Insofar as possible, categories between the two countries have been matched, but there remain minor differences. For example, the United States has not used the orbital launch platform concept on as large a scale; the Soviet Union has not designed special payloads to circle the Sun, measuring the interplanetary medium.

The table gives at least an indication as to the amount of activity by each country in major areas of space applications, such as weather, communications, and navigation. The United States has a large category of military missions not classified as to specific intent, beyond their developmental and support role. These have been grouped arbitrarily by orbital characteristics for approximate comparison purposes. Their groupings by possibly recoverable or non-recoverable categories may suggest parallels in mission, but public evidence is not conclusive.

TABLE 7 -- Summary of U.S. and Soviet Space Payloads by Mission
1957-1977

	United States	Soviet Union
Earth orbital science	167	133
Earth orbital engineering	21	2
Communications	128	238
Weather	70	45
Navigation	34	51
Geodesy	19	12
Earth resources	2	2
Military observation		
Low orbit recoverable (photo?)	227	393
Low orbit non recoverable (elint?)	75	56
Minor military	46	109
Early warning	37	11
Fractional orbit bombardment		18
Ocean surveillance	9	19
Interceptors and targets		29
Earth orbit man-related	11	39
Earth orbit manned	20	37
Lunar man-related	16	8
Lunar manned	20	
Moon unmanned programs	23	34
Mercury	1	
Venus	2	23
Mars	9	16
Outer planets	4	
Interplanetary space	7	
Vehicle tests	13	7
Subtotal	961	1,282
Orbital launch platform		161
Total	961	1,443

Mission assignments are arbitrary to a degree, and are subject to revision each year as more information becomes available.

VIII. LUNAR AND PLANETARY

The Soviet Union has made an effort comparable in number of flights committed to lunar and planetary work to the United States, but so far, has not gained as good results. Approximately 8.1 percent of Soviet flight attempts have been in the "escape mission" category, compared with the 8.8 percent in the United States.

A. Surveyor and Lunar Orbiter vs. Luna 4-14

In 1963, both the United States and the Soviet Union planned to land survivable payloads on the Moon. The U.S. program was called Surveyor, and in fact it did not fly until 1966, at which time it was a very great success. The several Surveyors which landed intact returned close to 100,000 pictures of their immediate surroundings and by remote control dug holes in the surface and also by an indirect means determined the chemical composition of the lunar soil.

By contrast, the Soviet Union did start landing attempts in 1963, but later by its own admission, Luna 4, 5, 6, 7, and 8 failed to achieve a survivable landing, and additionally, one unnamed flight and Kosmos 60 were lunar failures which did not leave Earth orbit. When Luna 9 in 1966 finally made it to the surface, the landing was not as gentle as a Surveyor landing, and the television camera returned only 27 pictures of the surroundings. Luna 13 additionally did impact testing of the soil with an extendable arm.

This comparison shows how difficult it can be to draw a balance sheet between two programs. U.S. Surveyors were more impressive than the Soviet Luna ships. But along with this, one must also note that Luna 9 landed a working camera before the first Surveyor, and the 27 pictures essentially answered the basic questions about the surface of the Moon, even though these did not compare in number with the thousands of pictures from Surveyor.

In the case of orbiters there were also different comparisons to draw, but the total usefulness of the U.S. Lunar Orbiters seems hard to contest. The Soviet Luna 10

reached a successful orbit before the first U.S. Lunar Orbiter, and its indirect measure told the Russians something of the probable composition of the lunar surface and also about gravity anomalies. Luna 12 in 1966 finally returned a few pictures to supplement earlier Soviet pictures taken of the far side by Luna 3 in 1959 and Zond 3 in 1965. But in no real sense did the few score Soviet pictures from these flghts come anywhere near the clarity, detail, and variety of the five sets of Lunar Orbiter views, each of which returned about 200 double frames (simultaneous views through narrow angle and wide angle lenses). The subsequent Luna 14 seems only to have been an extension of the work of the non-picture-taking Luna 10.

Zond 5 and 6, the 1968 unmanned precursors to projected later manned flights, did better in picture quality because they returned actual photographs to Earth in the same manner as was done shortly thereafter by Apollo 8. Zond 7 in 1969 and Zond 8 in 1970 performed tasks similar to those of the two preceding Zonds.

B. Soviet lunar sample return flights

In July 1969, the Russians sent Luna 15 to the Moon (using a large D class launch vehicle) at a time overlapping with the flight of Apollo 11. Its mission cannot be determined because it crashed during a soft landing attempt.

Luna 16 in 1970 maneuvered in lunar orbit, then landed, and by remote control bored a sample core 35 centimeters in length, weighing 101 grams, which was sealed in a container and rocketed back to Earth for recovery in the Soviet Union. Although the sample was small, it provided useful analytical material for a special quarantine laboratory similar to the Houston, Texas facility.

Luna 18 in 1971 on a similar mission made a bad landing, and was destroyed. Luna 20 in 1972 repeated the success of Luna 16, returning a sample from highlands, contrasted with the mare sample of its predecessor. Luna 23 in 1974 survived its landing, but its drill was damaged in landing, and after a few days the experiment was shut down without a sample return.

Luna 24 in 1976 was the most successful, being able to drill to a depth of 2 meters and returning all this sample core to Earth.

C. Soviet lunar surface roving vehicles

Luna 17 was the first successful landing of a Lunokhod roving vehicle weighing 756 kilograms. Landed November 17, 1970, it continued to function until October 4, 1971, traveling 10,540 meters over the surface, and returning 20,000 television views, 200 detailed panoramas, 500 soil-property tests, 25 soil chemical analyses, and a number of astronomical observations with its X-ray telescope.

Luna 21 in 1973 landed Lunokhod 2 of 840 kilograms, which operated for three months, but traveled 37,000 meters in that time, and returning proportionately more data and pictures also, despite its shorter life than Lunokhod 1.

D. Soviet lunar orbiters

The same D class launch vehicles used for the sample return and surface roamer missions was also used to place heavy payloads in lunar orbit. Luna 19 was sent to the Moon, in 1971, and remained under active control for about a year, gathering a wide variety of synoptic data and some pictures. Lune 22 in 1974 was a similar mission, remaining under active control for about a year and a half. During many maneuvers it was able to take high resolution pictures at some close approaches to the Moon.

E. U.S. planetary missions

The U.S. Mariner program has launched ten vehicles of which six returned planetary data. Mariner 2 and 5 brought back indirect readings from Venus. Mariner 4, 6, 7, and 9 brought back increasingly good pictures of the surface features of Mars. Mariner 10 not only returned good pictures of the cloud patterns of Venus, but made three photographic passes by Mercury with good results.

Pioneer 10 and 11 were able to bring back striking color pictures of Jupiter, and Pioneer 11 is now continuing on its way to Saturn for a fly-by in 1979.

Viking 1 and 2 have represented a climax in U.S. planetary efforts to date. The orbiters continue to map the surface of Mars and have also collected clear views of Deimos and Phobos. The landers have brought back color pictures from the surface, and their on-board laboratories have conducted a search for life with puzzling, inconclusive findings.

Voyager 1 and 2 were launched in 1977 toward Jupiter and the outer planets.

F. Soviet planetary missions

The commitment of payloads to planetary missions by the Russians has been much heavier than by the Americans, but with mixed results. Two Mars attempts as early as 1960 failed to reach even Earth orbit. In 1961, there were two Venus attempts, with Venera 1 reaching the vicinity of the planet in non-operating condition. In 1962, there were three more Venus attempts and three Mars attempts, with five of these payloads stranded Earth orbit, and Mars 1 in non-operating condition when it reached the vicinity of that planet. Zond 1, Venera 2, and Venera 3 were not in operating condition when they reached Venus. Zond 2 made a close fly-by of Mars in non-operating condition. Zond 3 was expended as a test flight taking pictures of the far side of the Moon and rebroadcasting these to Earth as it traveled as far as the orbit of Mars.

Results improved for the Russians when Venera 4, 5, 6, 7 and 8 all functioned to return direct readings within the atmosphere of Venus. Of these Venera 7 survived a Venus landing and broadcast for 23 minutes on the surface. Venera 8 had similar success, plus doing soil analyses.

As in the lunar program, the Russians shifted from use of the A class launch vehicle to the D class so that Venera 9 and 10 in 1975 accomplished the nearest Venus equivalent of American Viking missions to Mars. The orbital vehicles returned pictures and other data for many months in orbit. The landers operated about an hour on the surface, and their cameras returned good pictures of the farside surface, relayed via the orbiters. This was a remarkable feat, considering the 485°C. temperature.

The D class vehicle was also used for the launchings of Mars 2 through 7. Mars 3 was the first to make a survivable landing with television, but signals ceased before the first complete picture was received on Earth. Mars 4 and 5 were intended as orbiters working with Mars 6 and 7 landers. Of these four only Mars 5 attained an orbit and Mars 6 a landing. Mars 6 returned direct readings within the atmosphere but signals ceased at the surface.

Six other Venus related flights were stranded in Earth orbit over the years, in addition to those already mentioned. One other Mars flight ended in Earth orbit in addition to those mentioned earlier. There have also been press reports of additional Mars flight attempts which did not even reach Earth orbit, which reports are consistent with the failure of flights to appear to match the Russians' own predictions of their plans.

Had the heavy Mars vehicles of the U.S.S.R. been successful, many of the firsts of the Viking programs would have been Soviet prizes. Soviet orbiters in general put greater emphasis on a wide range of synoptic data readings, with color pictures less prominent than in the U.S. operations. The D class Soviet launch vehicle has demonstrated an ability to carry payloads up to 4,650 kilograms to Mars and 5,033 kilograms to Venus. The Venus landers weigh 1,560 kilograms each. These weights compare U.S. Vikings at 3,400 kilograms and Viking landers at 1,090 kilograms each.

G. Summary tables on lunar and planetary flights

The first table to follow summarizes the known lunar attempts of the two countries. The second table does the same for known planetary attempts. In both cases, the Soviet record may understate the realities because of their penchant for secrecy in hiding failures.

TABLE 8 -- Summary of Lunar Distance Flight Attempts

Launch date	Spacecraft name	Nation-ality	Weight (kg)	Cumulative national weight	Mission	Results
1958						
Aug. 17	Pioneer 0	US	38	38	Orbit Moon	Fail--exploded 16 km up.
Oct. 11	Pioneer 1	do	38	76	do	Fail--climbed 113, 830 km, fell back over South Pacific.
Nov. 8	Pioneer 2	do	39	115	do	Fail--climbed 1, 550 km, fell near Africa.
Dec. 6	Pioneer 3	do	6	121	Fly by Moon	Fail-climbed 102, 320 km, fell back over Africa.
1959						
Jan. 2	Luna 1	USSR	361	361	Strike Moon	Partial--missed Moon by 5-6, 000 km, entered solar orbit.
Mar. 3	Pioneer 4	US	6	127	Fly by Moon	Success--passed Moon at 60, 050 km, entering solar orbit.
Sep. 12	Luna 2	USSR	390	751	Strike Moon	Success--struck 335 km from visible center.
Sep. 24	Pioneer P-1	US	170	297	Orbit Moon	Fail--exploded in static test before launch.
Oct. 4	Luna 3	USSR	435	1, 186	Photo far side	Succeed--returned pictures of 70 percent of far side of Moon.
Nov. 26	Pioneer P-3	US	169	466	Orbit Moon	Fail--shroud tore away in launch, payload impacted near Africa.
1960						
Sep. 25	Pioneer P-30	do	176	642	do	Fail--impacted in Africa.
Dec. 15	Pioneer P-31	do	176	818	do	Fail--climbed 13 km and exploded.
1961						
Aug. 23	Ranger 1	do	306	1, 124	Vehicle test	Fail--intended to climb to 1, 102, 850 km, but stayed in low Earth orbit.
Nov. 18	Ranger 2	do	306	1, 430	do	Fail--intended to climb to 1, 102, 850 km, but stayed in low Earth orbit.
1962						
Jan. 26	Ranger 3	do	330	1, 760	TV, hard land	Partial--missed Moon by 36, 808 km, no TV pictures or landed instruments.

TABLE 8 -- continued

Launch date	Spacecraft name	Nation-ality	Weight (kg)	Cumulative national weight	Mission	Results
Apr. 23	Ranger 4	US	331	2,091	TV, hard land	Partial--timer failed, fell on far side of Moon, no pictures.
Oct. 18	Ranger 5	do	342	2,433	do	Partial--power failure, so missed Moon by 725 km, entered solar orbit.
1963						
Jan. 30	Unan-nounced	USSR	1,400?	2,586	Moon soft land	Fail--Earth orbit only.
Apr. 2	Luna 4	do	1,422	4,008	do	Partial--missed Moon by 8,500 km, barycentric or solar orbit.
1964						
Jan. 30	Ranger 6	US	365	2,798	TV before strike	Partial--on target, but no pictures taken.
Jul. 28	Ranger 7	do	366	3,164	do	Success--returned 4308 pictures of Moon to impact.
Dec. 11	Centaur 2	do	952	4,116	Vehicle test	Fail--did not restart and soon fell in Australia.
1965						
Feb. 17	Ranger 8	do	367	4,483	TV before strike	Success--returned 7,137 pictures of Moon to impact.
Mar. 2	Centaur AC 5	do	635	5,118	Vehicle test	Fail--exploded at pad.
Mar. 12	Kosmos 60	USSR	1,470	5,478	Moon soft land	Fail--Earth orbit only.
Mar. 21	Ranger 9	US	366	4,484	TV before strike	Success--returned 5,814 pictures of Moon to impact.
May 9	Luna 5	USSR	1,476	6,954	Moon soft land	Partial--retrofire failed, impacted Moon.
June 8	Luna 6	do	1,442	8,396	do	Partial--missed Moon by 160,000 km, entered solar or barycentric orbit.
July 18	Zond 3	do	890?	9,286	Photo far side	Success--returned 25 pictures, entered solar oribit.
Aug. 11	Centaur 3	US	952	6,436	Vehicle test	Success--reached 820,824 km out with Surveyor dynamic model, in barycentric orbit.

TABLE 8 -- continued

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
Oct. 4	Luna 7	USSR	1,506	10,792	Moon soft land	Partial--retrofired early, fell on Moon.
Dec. 3	Luna 8	do	1,552	12,344	do	Partial--retrofired late, fell on Moon.
1966						
Jan. 31	Luna 9	do	1,583	13,927	do	Success--returned 27 pictures from lunar surface.
Feb. 26	Apollo-Saturn 201	US	15,331	27,767	Vehicle test	Success--flew suborbitally to land in the Pacific.
Mar. 1	Kosmos 111	USSR	1,600?	15,527	Moon orbit	Fail--Earth orbit only.
Mar. 31	Luna 10	do	1,600	17,127	do	Succeed--returned physical measurements from lunar orbit.
Apr. 8	Centaur 4	US	771	28,538	Vehicle test	Fail--low Earth orbit only.
May 30	Surveyor 1	do	995	29,533	Moon soft land	Succeed--returned 11,237 pictures from lunar surface.
July 1	Explorer 33	do	93	29,626	Moon orbit	Partial--failed to approach Moon at right speed, so in barycentric orbit.
July 5	Apollo-Saturn 203	do	26,535	56,161	Vehicle test	Success--simulated in Earth orbit a Saturn V flight.
Aug. 10	Lunar Orbiter 1	do	387	56,548	Moon orbit	Success--returned 414 pictures of potential landing sites on Moon.
Aug. 24	Luna 11	USSR	1,604?	18,767	do	Success--but failed to return pictures from lunar orbit.
Aug. 25	Apollo-Saturn 202	US	20,275	76,823	Vehicle test	Success--simulated reentry in suborbital flight.
Sep. 20	Surveyor 2	do	1,000	77,823	Moon soft land	Partial--stabilization failed, struck Moon.
Oct. 22	Luna 12	USSR	1,625?	20,392	Moon orbit	Success--returned pictures of Moon.
Oct. 26	Centaur 5	US	726	78,549	Vehicle test	Success--mass model of Surveyor carried to 465,032 km.
Nov. 6	Lunar Orbiter 2	do	390	78,939	Moon orbit	Success--returned 422 pictures of Apollo sites, far side.
Dec. 21	Luna 13	USSR	1,595?	21,987	Moon soft landing	Success--returned pictures and soil density measures.
1967						
Jan. 27	Apollo-Saturn 204	US	20,412	99,351	Capsule test	Fail--Burned on pad in exercise.

TABLE 8 -- continued

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
Feb. 5	Lunar Orbiter 3	US	385	99,736	Moon orbit	Success--returned 307 pictures of Apollo sites.
Apr. 17	Surveyor 3	do	1,035	100,771	Moon soft land	Success--returned 6,315 pictures, dug soil with shovel.
May 4	Lunar Orbiter 4	do	390	101,161	Moon orbit	Success--returned 326 pictures of large areas of the Moon.
July 14	Surveyor 4	do	1,039	102,200	Moon soft land	Partial--signals ceased at touch-down on Moon.
July 19	Explorer 35	do	104	102,304	Moon orbit	Success--returned data from lunar orbit.
Aug. 2	Lunar Orbiter 5	do	390	102,694	do	Success--returned 424 pictures including much of far side.
Sep. 8	Surveyor 5	do	1,005	103,699	Moon soft land	Success--returned 18,006 pictures, chemical analysis of soil.
Nov. 7	Surveyor 6	do	1,008	104,707	do	Success--returned 30,065 pictures, chemical and mechanical soil study.
Nov. 9	Apollo 4	do	42,506	147,213	Vehicle test	Success--simulated full lunar return reentry in Earth orbit.
1968						
Jan. 7	Surveyor 7	do	1,040	148,253	Moon soft land	Success--returned 21,274 pictures, chemical analysis of soil from trench it dug.
Jan. 22	Apollo 5	do	14,379	162,632	Vehicle test	Success--tested lunar module in Earth orbit.
Mar. 2	Zond 4	USSR	5,800?	27,787	do	Partial--flew to lunar distance but recovery in doubt.
Apr. 4	Apollo 6	US	42,577	205,209	do	Partial--did not go to lunar distance, but recovered payload.
Apr. 7	Luna 14	USSR	1,615?	29,402	Moon orbit	Success--returned data on lunar mass distribution.

TABLE 8 -- continued

Launch date	Spacecraft name	Nation-ality	Weight (kg)	Cumulative national weight	Mission	Results
Sep. 14	Zond 5	USSR	5,800?	35,202	Circumlunar	Success--ballistic reentry with biological subjects and pictures.
Oct. 11	Apollo 7	US	20,577	225,786	Manned test	Success--flew in Earth orbit.
Nov. 10	Zond 6	USSR	5,800?	41,002	Circumlunar	Success--lifting reentry with biological specimens and pictures.
Dec. 21	Apollo 8	US	43,654	269,440	Moon orbit	Success--men in lunar orbit and recovered.
1969						
Mar. 3	Apollo 9	do	47,167	316,607	Manned test	Success--tested lunar module rendezvous, crew recovered.
May 18	Apollo 10	do	48,638	365,245	Moon orbit	Success--tested lunar module rendezvous at Moon, crew recovered.
July 13	Luna 15	USSR	5,800?	46,802	Moon soft land	Partial--lunar orbit success, but landing failed.
July 16	Apollo 11	US	49,698	414,943	do	Success--first manned landing on Moon and return.
Aug. 7	Zond 7	USSR	5,800?	52,602	Circumlunar	Success--lifting reentry of photographs.
Sep. 23	Kosmos 300	do	5,800?	58,402	Moon soft land	Fail--Earth orbit only.
Oct. 22	Kosmos 305	do	5,800?	64,202	do	Fail--Earth orbit only.
Nov. 14	Apollo 12	US	49,804	464,747	do	Success--manned lunar landing and return with part of Surveyor 3.
1970						
Apr. 11	Apollo 13	do	49,990	514,737	do	Partial--explosion in service module limited flight to circumlunar; crew saved.
Sep. 12	Luna 16	USSR	5,800?	70,002	do	Success--made automated sample collection, returned it to Earth.
Oct. 20	Zond 8	do	5,800?	75,802	Circumlunar	Success--ballistic reentry with photographs.

TABLE 8 -- continued

Launch date	Spacecraft name	Nation-ality	Weight (kg)	Cumulative national weight	Mission	Result
Nov. 10	Luna 17	USSR	5,800?	81,602	Moon soft land	Success--landed automated roving vehicle for long term exploration.
1971						
Jan. 31	Apollo 14	US	46,346	561,083	do	Success--manned lunar landing and return.
July 26	Apollo 15	do	52,759	613,842	do	Success--manned lunar landing, roving vehicle, safe return.
Sep. 2	Luna 18	USSR	5,800?	87,402	do	Partial--lunar orbit success, but crashed on landing.
Sep. 28	Luna 19	do	5,800?	93,202	Moon orbit	Success--returned photographs and other data.
1972						
Feb. 14	Luna 20	do	5,800?	99,002	Moon soft landing	Success--made automated sample collection, returned it to Earth.
Apr. 16	Apollo 16	US	48,606	662,448	do	Success--manned lunar landing, roving vehicle, safe return.
Dec. 7	Apollo 17	do	46,825	709,273	do	Success--manned lunar landing, roving vehicle, safe return.
1973						
Jan. 8	Luna 21	USSR	5,800?	104,802	do	Success--landed automated roving vehicle for long term exploration.
June 10	Explorer 49	US	328	709,601	Moon orbit	Success--radio astronomy from far side of Moon.
1974						
May 29	Luna 22	USSR	5,800?	110,602	do	Success--returned pictures and data.
Oct. 28	Luna 23	do	5,800?	116,402	Moon soft land	Partial--landed safely, but drill damaged so no sample returned to Earth.
1976						
Aug 9	Luna 24	do	5,800?	122,202	do	Success--made automated sample collection, returned to Earth.

NOTES

1. The table includes all known attempts to send payloads to the Moon or to distances from Earth equal to the distance of the Moon from Earth, together with test flights in Earth orbit of lunar-associated hardware. It cannot include Soviet flight failures which did not reach Earth orbit because these are not in the public domain.

2. Weights listed are in kilograms, with a second column showing a running total of kilograms for all flights to data of the same national origin.

3. In a very few instances, the mission has been assigned by inference, in terms of the context of the time in which it took place.

4. The test of success or failure is somewhat arbitrary. Any flight staying in relatively low Earth orbit as well as not achieving Earth orbit is counted as a failure. Flights which at least approached the Moon, although not achieving the estimated goal received the rating of partial success.

5. The Soviet label Luna was applied after the fact to the first flights which at the the were simply called Cosmic Rockets, with the third one called an Automatic Interplanetary Station (AIS 1). Luna 1 was also called Mechta (Dream).

SOURCES: Soviet data are from Soviet TASS bulletins for the most part, supplemented by inferential judgments that some Earth orbital flights were almost certainly lunar attempts which failed, based upon the timing of the launch, the nature of the debris in Earth orbit, the launch vehicle used, and the orbital path chosen. U.S. data are based mostly on NASA press releases, although the first lunar attempt was sponsored and reported on by the Advanced Research Projects Agency (ARPA) of the Department of Defense before the creation of NASA. Estimated weights of Luna 11, 12, 13 and 14 by D.R. Woods, whose generalized estimate on later Luna and Zond flights also has been used.

TABLE 9 -- Summary of Planetary Distance Flight Attempts

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
1960						
Mar. 11	Pioneer 5	US	43	43	Interplanetary toward Sun	Success--returned data from 36.2 million kilometers.
Oct. 10	Unacknowledged	USSR	640?	640?	Mars	Fail--did not reach Earth orbit.
Oct. 14	do	do	640?	1,280	do	Fail--did not reach Earth orbit.
1961						
Feb. 4	Tyazheliy Sputnik 4	do	640?	1,920	Venus	Fail--Earth orbit only.
Feb. 12	Venera 1	do	644	2,564	do	Partial--Communications failed; passed Venus at 100,000 km.
1962						
July 22	Mariner 1	US	202	245	Venus flyby	Fail--destroyed at 160 km. altitude.
Aug. 25	Unacknowledged	USSR	890?	3,454	Venus	Fail--Earth orbit only.
Aug. 27	Mariner 2	US	203	408	Venus flyby	Success--passed Venus at 34,853 km.
Sep. 1	Unacknowledged	USSR	890?	4,344	Venus	Fail--Earth orbit only.
Sep. 12	Unacknowledged	do	890?	5,234	do	Fail--Earth orbit only.
Oct. 24	Unacknowledged	do	890?	6,124	Mars	Fail--Earth orbit only.
Nov. 1	Mars 1	do	894	7,018	do	Partial--communications failed, passed Mars at 191,000 km.
Nov. 4	Unacknowledged	do	890?	7,908	do	Fail--Earth orbit only.
Nov. 11	Kosmos 21	do	890?	8,798	Venus test	Fail--Earth orbit only.
1964						
Mar. 27	Kosmos 27	do	890?	9,688	Venus	Fail--Earth orbit only.
Apr. 2	Zond 1	do	890?	10,578	do	Partial--communications failed, passed Venus at 100,000 km.
Nov. 5	Mariner 3	US	261	669	Mars flyby	Fail--shroud did not separate, thrown into wrong orbit.
Nov. 28	Mariner 4	do	261	930	do	Success--returned 22 pictures.
Nov. 30	Zond 2	USSR	890?	11,468	Mars	Partial--communications failed, passed Mars at 1,500 km.

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TABLE 9 -- continued

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
1965						
July 18	Zond 3	USSR	890?	12, 358	Mars test	Success--returned 25 pictures of Moon far side, retransmitted from increasing distances.
Nov. 12	Venera 2	do	963	13, 321	Venus flyby	Partial--communications failed, passed Venus at 24, 000 km.
Nov. 16	Venera 3	do	960	14, 281	Venus land	Partial--communications failed, struck Venus 450 km. from visible center.
Nov. 23	Kosmos 96	do	960?	15, 241	Venus	Fail--Earth orbit only.
Dec. 16	Pioneer 6	US	61	991	Interplanetary toward Sun	Success--returned data.
1966						
Aug. 17	Pioneer 7	do	61	1, 052	Interplanetary away from Sun	Success--returned data.
1967						
June 12	Venera 4	USSR	1, 106	16, 347	Venus land	Success--returned direct readings of atmosphere to 25 km. altitude.
June 14	Mariner 5	US	245	1, 297	Venus flyby	Success--returned data, passed Venus at 4, 094 km.
June 17	Kosmos 167	USSR	1, 100?	17, 447	Venus	Fail--Earth orbit only.
Dec. 13	Pioneer 8	US	66	1, 363	Interplanetary away from Sun	Success--returned data.
1968						
Nov. 8	Pioneer 9	do	67	1, 430	Interplanetary toward Sun	Success--returned data.
1969						
Jan. 5	Venera 5	USSR	1, 130	18, 577	Venus land	Success--returned direct readings of atmosphere to near surface.

TABLE 9 -- continued

Launch date	Spacecraft name	Nation- ality	Weight (kg)	Cumulative national weight	Mission	Results
Jan. 10	Venera 6	USSR	1,130	19,707	Venus land	Success--returned direct readings of atmo- sphere to near sur- face.
Feb. 24	Mariner 6	US	380	1,810	Mars flyby	Success--returned 24 pictures and other data.
Mar. 27	Mariner 7	do	380	2,190	do	Success--returned 31 pictures and other data.
Aug. 27	Pioneer E	do	66	2,256	Interplan- etary at Earth orbit	Fail--destroyed by range safety.
1970						
Aug. 17	Venera 7	USSR	1,180	20,887	Venus soft land	Success--sent back data from atmosphere and surface of Venus.
Aug. 22	Kosmos 359	do	1,180	22,067	do	Fail--Earth orbit only.
1971						
May 8	Mariner 8	US	1,029	3,285	Mars orbit	Fail--fell in Atlantic Ocean
May 10	Kosmos 419	USSR	4,650?	26,717	Mars soft land	Fail--Earth orbit only.
May 19	Mars 2	do	4,650	31,367	do	Partial--returned datafrom orbiter, but lander destroyed.
May 28	Mars 3	do	4,650	36,017	do	Success--returned orbital data and survived landing.
May 30	Mariner 9	US	1,030	4,315	Mars orbit	Success--returned 6,786 pictures of Mars.
1972						
Mar. 3	Pioneer 10	do	258	4,573	Jupiter flyby	Success--returned pictures and other data.
Mar. 27	Venera 8	USSR	1,180?	37,197	Venus soft land	Success--atmospheric data and soil analysis re- turned.
Mar. 31	Kosmos 482	do	1,180?	38,377	do	Fail--Earth orbit only.
1973						
Apr. 6	Pioneer 11	US	259	4,832	Jupiter, Saturn flyby	Success--returned Jupiter pictures and data; Saturn not yet reached.
July 21	Mars 4	USSR	4,150?	42,527	Mars orbit	Partial--returned data and in flyby, but did not enter orbit.

TABLE 9 -- continued

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
July 26	Mars 5	USSR	4,150?	46,677	Mars Orbit	Success--returned data and pictures.
Aug. 6	Mars 6	do	4,150?	50,827	Mars soft land	Partial--returned data from flyby, but lander signals ceased.
Aug. 9	Mars 7	do	4,150?	54,977	do	Partial--returned data from flyby, but lander missed by 1,300 km.
Nov. 3	Mariner 10	US	504	5,336	Venus, Mercury flyby	Success--returned pictures from Venus and three times pictures from Mercury.
1974						
Dec. 10	Helios 1	German Fed. Rep./US	370	5,706	Sun approach	Success--returned data.
1975						
June 8	Venera 9	USSR	4,936	59,913	Venus soft land	Success--returned pictures and other data.
June 14	Venera 10	do	5,033	64,946	do	Success--returned pictures and other data.
Aug. 22	Viking 1	US	3,400	9,106	Mars soft	Success--returned pictures and other data.
Sep. 9	Viking 2	do	3,400	12,506	do	Success--returned pictures and other data.
1976						
Jan. 15	Helios 2	German/Fed. Rep./US	376	12,882	Sun approach	Success--returned data.
1977						
Aug. 20	Voyager 2	US	700	13,582	Jupiter	en route
Sep. 5	Voyager 1	do	700	14,282	Jupiter	en route

NOTES

1. The table includes all known attempts to send payloads to the planets or into solar orbit, not including those intended to go to the Moon which only incidentally may have escaped barycentric orbit to enter heliocentric orbit. It cannot include additional Soviet flight failures which did not reach Earth orbit, when not in the public domain. The only year in which there had been persistent reports of Soviet intentions to launch planetary flights for which there is no public record of failures is 1969. This could mean that Mars flights using the D-1-e vehicle began in that year, but failed to reach Earth orbit.

2. Weights listed are in kilograms, with a second column showing a running total of kilograms for all flights to data of the same national origin.

3. In a few instances, the mission has been assigned by inference, in terms of the context of the time in which it took place. Some of the Soviet flights to the planets may have been orbiters or landers, but no attempt has been made to guess the mission other than that of the planet name.

4. The test of success or failure is somewhat arbitrary. Any flight staying in relatively low Earth orbit as well as those not achieving Earth orbit are counted as failures. Flights at least approaching interplanetary distances although not achieving their estimated goal received the rating of partial success.

SOURCES: Soviet data are from Soviet TASS bulletins for the most part, supplemented by inferential judgments that some Earth orbital flights were almost certainly planetary attempts which failed, based on the timing of the launch, the nature of the debris in Earth orbit, the launch vehicle used, and the orbital path chosen. U.S. data are based mostly on NASA press releases. Weight estimates for the more recent Mars and Venus flights by the Russians have been varied from the weight of Mars 2 and 3 at the suggestion of D.R. Woods and C.P. Vick, to reflect approximate energy requirement effects on payloads.

IX. FUTURE DIRECTIONS FOR THE SPACE PROGRAMS

Attempting to predict the future of the space program is a difficult assignment as it depends upon political decisions as much as on technical capabilities. At least, there are more engineering possibilities than there are financial resources likely to be made available to pursue them. The issue of future goals has been with the United States for several years, particularly after the accomplishment of the dominating Apollo mission.

Estimating what the Soviet Union will elect to do in space may be even harder for a Western observer because of Soviet restrictions on freedom of information. The United States abounds in paper plans, but until the President and the Congress agree on funding, U.S. plans stay on paper, and there is no formal commitment to go ahead. In the Soviet case, they have stated at several levels of authority, including the highest, more positively their long run goals, although without a real, public timetable. They, too, undoubtedly have to face hard budget choices before actual hardware work can begin.

The announced Soviet goal is a comprehensive exploitation of space technology including the exploration and settlement (where practical) of the planets, along the way exploring the Moon in greater detail, and using Earth orbital stations for a host of practical purposes. The immediate purpose of this paper is again to pose questions about the choices immediately before each country, and to estimate how well they should be able to respond.

A. The space shuttle: What are the implications for each country?

NASA has made its principal development program for the 1970's the creation of a reusable shuttle spacecraft to act as a ferry from Earth to orbit and return. Over a period of time, various configurations have been studied. The favored design for a period was for two completely reusable piloted stages. The booster stage would have been roughly the size of a 747 or C-5A; and the orbital stage about the size of a

DC-8 or 707. Both were to be rocket-powered, burning hydrogen and oxygen. After a vertical takeoff with the two craft attached in parallel, the booster was soon to fly back to the launch site to be readied for the next trip. The upper stage was to fly on to orbit, and later return for reuse. Both stages were to land horizontally like aircraft. Analysis showed that although these craft represented an economical combination in the long run, they involved cost-peaking problems during development which made their fiscal and political practicability questionable.

The plan finally proposed in early January 1972 traded off some reusability for annual development cost totals which could be given consideration within the kind of budget ceilings with which NASA has worked in recent years. This compromise offered fewer cost savings in flight operations, but was believed by NASA to represent the only approach which was feasible under existing fiscal conditions. It was hoped by the sponsors that the booster stage could be replaced later by a fully reusable design. What is now being built is a reusable orbital stage about the size of a DC-9, powered by three hydrogen-oxygen engines and a large external disposable and non-recoverable fuel tank. It will carry useful payloads measuring up to 4.6 meters in diameter by 18.3 meters long, and weighing up to 29,480 kilograms. It will carry a crew of two, plus two passengers, with the capability of carrying more passengers in special modules in the payload bay, and with a flight environment which would not require the special training and stresses of present astronaut flight. It will stay in orbit for periods ranging from a week to a month. Its tasks will include ferrying people and supplies, supporting a Spacelab, launching other satellites, and potentially even acting as a rescue ship. It may service other spacecraft in orbit, bringing them back to Earth for major overhaul if required.

The interim booster will consist of two strap-on solid-fuel rockets which after use will be jettisoned into the ocean and recovered for refurbishment and reuse.

Replacing most existing launch vehicles, the shuttle is expected to bring down the launch cost per kilogram of payload somewhat. (Pricing policy is arbitrary so quoting a figure is difficult.) But even greater savings are expected ultimately in the redesigning and new applications of payloads. Although the $5.22 billion (in 1971 dollars) estimated development cost is substantial even if the program is kept within costs, any continuing space program of the dimensions of the present one is expected to permit the shuttle to pass a breakeven point and bring substantial savings within the effective life of this system. With more experience, parametric studies suggest, future shuttle systems, perhaps single stage to orbit, may reduce costs still another order of magnitude below those estimated for this first generation shuttle.

NASA is not only staking on the shuttle its only chance to continue a manned program, but is predicating its unmanned flights on use of this system as the most economical way of making future progress. The plan was no sooner announced than it came under attack in some quarters as a mistaken assessment of national priorities. Critics said it was likely to face future cost overruns, and the size of the mission model was disputed as optimistically large (assuming more flights than in fact will occur). But the ultimate test of success if the program is seen through to operation, will lie in the actual performance.

The Soviet Union has shown an equal awareness of the potential of reusable vehicles, and various Russian space officials have stated their own convictions that such development is essential. But in keeping with Soviet practice, internal debates, or even decisions without debate, about new technology are not exposed in any public forum, so the current status of the Soviet effort, if any, in this regard is not known. Considering the Soviet effort to maintain a position of leadership in space, and the continued high level of Soviet flight activity (triple that of the United States), they have even more compelling reasons to develop a reusable shuttle as a cost saving device. It is hard to imagine their attainment of announced goals, to be discussed presently, without use of a shuttle.

B. Manned space stations in Earth orbit: What are the plans of each country?

The United States cancelled Apollo lunar landing missions after Apollo 17 and made available for space station work Saturn V launch vehicle from our remaining small stockpile, now that production of these launch vehicles has ceased. Our experimental space station is called Skylab, and was launched on a Saturn V in 1973. The station has been built in the shell of an S-IVB rocket stage, and is accompanied by an associated docking adapter, air lock, and telescope mount. It is not likely to be used again for continued habitation but could be visited by a space shuttle.

Plans for a military Manned Orbiting Laboratory (MOL) have long since been abandoned because of budget squeeze and changing technology. Despite the similarity of name, this alternate program was to operate in so different a mode that it was never competitive with Skylab; the only common factor was that it was manned.

In September 1969, a special task group reporting to the President recommended a four-element program for the 1970's which included the already described space shuttle, a versatile space tug for extensive maneuvering in orbit or landing on the Moon, a nuclear-powered rocket ferry for transfers between Earth orbit and lunar or planetary orbits, and a building block system of modules to construct permanent space stations in Earth orbit, and elsewhere. The program was carefully considered technologically, but it involved fiscal peaking problems which were given small chance of winning general national support. Hence, the present effort to build the shuttle is the only one of the four elements recommended by the Administration for active development (aside from interim upper stages).

Part of the gap in the U.S. program will be filled by the Europeans who are to build a manned sortie module (Spacelab) to be carried in the shuttle. But because it is not detached from its shuttle ferry, it is not a real substitute for any proposed station module.

Only low level study and component development is underway for a U.S. space station module, as a potential follow-on to the interim Skylab. The paper concept calls

for 12-man modules to be carried to orbit by the shuttle, and these could be linked to make versatile stations housing up to 100 scientists and engineers with stay times ranging up to one year. Modules would be built for various functions and then joined to meet needs. While the main station would be in a fairly low Earth orbit, later modules might be used for other purposes such as 24-hour synchronous high orbit, lunar orbit, and deep space flight.

The Soviet Union claimed that its docked combination of Soyuz 4 and 5 in January 1969 represented a rudimentary space station, inasmuch as there were four rooms assembled with four men present. But the ships were docked only a few hours, and the transfer of crews had to be done by EVA, rather than crawling through a connecting tunnel. The ASTP was a slightly better claim to such a label.

The Salyut space stations from 1971 on can make a real claim to their title, even though the over 25,000 kilogram combined weight (with Soyuz) and 100 cubic meters of interior space fall well short of the 82,235 kilograms and 357 cubic meters of Skylab. The advantage of Salyut is that it is an on-going and evolving program.

For the future, the Russians speak confidently of building a large and permanent orbital station for many men, for the purpose both of conducting Earth applications work and scientific observation of the stars, and additionally serving as an orbital assembly, checkout, and launch facility to send manned expeditions to the Moon and planets. Keldysh, then President of the Soviet Academy of Sciences, predicted in October 1969 that such a station might be ten years away but would more likely be available in five years. (It is not yet here.) It may be that the long awaited new large (G) launch vehicle will find use in lifting major components for such a station. Using this vehicle, the U.S.S.R. could put up its equivalent of the U.S. Skylab any time from 1978 on. There is more discussion world-wide than firm planning for space colonies which are receiving press and professional attention. A favorite scheme is the L-5 proposal to be positioned in Earth orbit as far away as the Moon at a La Grangian point.

C. Manned lunar landing: Are the Russians still interested?

When President Kennedy in 1961 asked Congress to support Project Apollo, his advisors had told him this was a project in which the United States had a good chance of being first. They were right, but it would have taken very little different to have come in second.

Many analysts had expected the Russians to be first to make a manned circumlunar flight, possibly to coincide with the fiftieth anniversary of the Soviet state in November 1967. The program slipped, but now unmanned precursors have accomplished this mission with improving success, although men have not yet been committed. Instead, Apollo 8 was first to carry men to the Moon, and additionally it lingered in lunar orbit, something beyond the capability of the Zond 4 through 8 flights.

In the early 1960's Khrushchev made seemingly contradictory statements as to whether the Soviet Union was working actively on a lunar landing program, but in net balance his statements and those of other Soviet officials seemed to indicate they were. Until a few months before the Apollo 8 flight, Soviet cosmonauts were saying that when the Americans landed, they would find the Russians there to greet them. This talk ceased until new predictions were made in 1969. In April and June, respectively, Shatalov and Leonov, both cosmonauts, predicted that a Soviet manned landing and return would be accomplished some time between October 1969 and the early part of 1970, preceded by some unmanned tests of the entire system. This would seem to indicate that Soviet space officials thought whatever engineering difficulties which had held up the unveiling of their very large (G) vehicle had finally been solved.

In actual fact, the absence of appropriate Soviet flights during the summer and fall of 1969 probably indicated that whatever hopes were present in the spring had not been fulfilled. In the October statement by Keldysh, referred to above, he suggested that immediate plans for manned lunar flights had been set aside, but not precluded for the future. This admission in itself seemed to give substance to there having

been such plans earlier. Further, the statement had the advantage of taking the public pressure off their program in the face of delays. But it must be added, it is not clear from what is known of the Soviet program that they had the means to conduct at so early a time a manned lunar landing. Not only would the expected big G vehicle have to be operational, but it would require either high energy upper stages, or have to be used in some pattern of rendezvous operations. The lack of evidence of readiness to go either of these paths as early as 1969 surrounds the cosmonaut predictions with questions. There is circumstantial evidence that subcomponents for manned lunar flights beyond the Zond circumlunar program were flight tested by Kosmos 159 (1967), Kosmos 379 and 382 (1970) and Kosmos 398 and 434 (1971). Some of these might have been used for future lunar orbit rendezvous options as their changes of velocity matched requirements for entering lunar orbit and for descending to the surface of the Moon, and returning to Earth.

Continued slippages in those parts of the Soviet program potentially related to a manned lunar landing suggest that the first flights could not come probably much before the late 1970's, and more likely will be later. If such flights come before the establishment of an orbital launch facility in conjunction with a permanent Soviet space station, they would in most likelihood parallel the kind of interim approach used in Apollo, although possibly differing in detail. In December 1974, the Russians asked India for permission to base tracking and recovery ships in that country, strongly, suggesting a continued current interest in lunar recovery missions with a g-load low enough to carry men as in the cases of the Zond flights. However, no new flights have occurred since then to support any development.

In summary, a Soviet manned lunar landing does not seem imminent, but is still expected as a part of Soviet long range plans. Going to the Moon with men has been talked about so long and prepared for at such expense by the Russians that one must assume they will proceed as soon as they solve their present problems of unreliability

of hardware. Our first clues may come from appropriate precursor flights, particularly of the big G vehicle, but also possibly in use of high energy upper stages, and further tests of multiple-burn maneuvering stages.

D. What other major plans for exploration are likely to come in the near term?

Despite the shrinkage which has occurred in the NASA program, and the fact that the shuttle is absorbing a large part of the funds during the six years of its development, NASA still has an interesting array of experiments in preparation. For example, the first flights through the asteroid belt to Jupiter are over, as is the first flight to Mercury (via Venus). The arrival of Pioneer 11 at Saturn lies ahead. Viking experiments at Mars will continue for a time. Now being readied are Pioneer payloads with multiple atmospheric probes for the atmosphere of Venus. Also, two Voyagers are on the way to more detailed studies of Jupiter and Saturn. More Landsat missions, a Seasat, and more High Energy Astronomical Observatories are other projects expected to be flown. Additionally there are a number of co-operative applications flights for NOAA, ComSat Corp. and other nations.

Although the Soviet Union does not discuss specific flight plans in advance, it has put on the record a variety of commitments in principle and of intent to conduct a wide-ranging program of solar system exploration and of Earth applications.

E. How do the two countries plan to compete in space applications?

It is within the expected capacity of the United States to improve the completeness and quality of its weather reporting, with some good prospect for providing accurate forecasts of a week or so.

The Soviet Union will probably improve the reliability of its weather satellite equipment, and they are also interested in providing better forecasts. Their theory of weather systems may keep pace with ours, but they may lag for a time in computer capacity on the ground to support weather analysis.

The United States is working with IntelSat, the international consortium, to provide a growing number of channels to all parts of the world for telephone, television, and computer links. Direct broadcast will come more slowly for reasons of political concern and limited channel capacity. Domestic distribution of communications by satellite had finally appeared in 1974 but was delayed by the dispute over control of such systems.

The Soviet Union has tried to interest other countries in a Soviet communications satellite system called InterSputnik, but this has had such a poor reception that the plan has advanced slowly. About five years late, Soviet television service to Cuba has opened. In late 1975 InterSputnik received a new lease on life with the plan to launch up to eleven large Statsionar satellites in 24-hour synchronous orbit between 1975 and 1980.

The Earth resources field is one which suggests a large expansion of space activity in the next decade. The United States seems likely to go ahead with operational systems, and it would be hard to believe the Russians would neglect further Earth resources work, although their comprehensive plans are not known.

Air traffic control using satellites as part of the system (Aerosat) has had its ups and downs in official support after some years of study and debate. Other nations also have a stake in such plans. A Marisat system is now in place to aid ship communications, but this is still an interim system.

F. <u>What are the prospects for manned flights to the planets?</u>

For a number of years, NASA has studied various kinds of manned planetary expeditions, principally to Mars. Briefly, there was interest some years ago in a fly-by of Mars and possibly of Venus by the late 1970's, using modified Apollo and Saturn V equipment, but this was not seriously entertained in any formal program. When the President's Space Task Group in the summer of 1969 submitted its long range U.S. space plan, it opened the possibility of a Mars landing by men in the 1980's.

The general reaction in the Congress with few exceptions was either indifference or active hostility, and NASA has not pressed this possibility in its official plans.

As mentioned earlier in this paper, a national capability to use space in the late 1970's and thereafter was to be build around use of four types of largely reusable and multipurpose vehicles. The shuttle, already discussed, is the first and most vital. It is important to recognize that the shuttle is not intended to be an end in itself, but represents a design approach to cutting costs for all kinds of missions, whether unmanned, or manned, and whether in Earth orbit or beyond. The second element, already discussed, is the manned station module. This is expected to justify its costs of development and use in practical applications in Earth orbit once such a reliable unit is available, and the shuttle permits non-astronauts and less expensive payloads to fly to and from orbit safely at more moderate cost. Purely as a dividend, such a unit could also be used at nominal additional cost in orbit around the Moon, on the surface of the Moon, or for flight to the planets.

A third element is a space tug, to be used in assembling components in the vicinity of the future permanent space station, shifting payloads to synchronous orbit, or landing major components on the Moon as successor to the transport capabilities of the present lunar module.

Only the fourth element of the proposed national program is aimed primarily at deep space work: the nuclear-powered orbital transfer shuttle, also reusable, both for major movements to and from the Moon or in planetary flight. (Now of course, all nuclear propulsion development has been halted.)

When some Members of Congress reacted so negatively to the report of the Space Task Group, the very existence of the shuttle, which is so important to cutting costs near Earth, was threatened by the charge that it represented a back-door attempt to gain a manned planetary program without explicit approval. Consequently, little about planetary flight has been said since then by NASA in connection with the shuttle or other program elements.

When the United States decided to send men to the Moon, it had to construct an entirely new capability whose cost totaled $21.35 billion up through the first landing. Successive flights were priced at $450 million or so, once the initial investment had been made. It was not surprising in discussing the much greater challenge of manned planetary flight that it soon became common in political circles to put a $100 billion price tag on a first expedition to Mars. Considering that equipment would have to work reliably for about two years instead of two weeks, the needed redundancy for safety as well as the initial logistics requirements would add up to a fairly ambitious undertaking if the Saturn V and Apollo technology of 1961 were to be used. Human health reactions on such a long flight have also been questioned, despite some partial long-duration tests of closed cabins on Earth, as well as use of the Skylab flights.

The motivation for the Space Task Force plan was by no means exclusively for creating a capability to fly to Mars; but perhaps the number of words devoted to the subject in the report, related in part to sounding out public support for an inspiring new goal, was misplaced in the climate of apathy and even hostility which followed so quickly after the Apollo 11 success.

The marginal cost per kilogram of using the shuttle to attain Earth orbit was originally expected to drop from $1,500 to about $330 a kilogram in the first generation of this class. This cost advantage has largely eroded away, with the principal hope of breaking even with expendable vehicles on launch costs. However, the shuttle also affords major opportunities to cut the cost of payloads through changing the flights environment, removing the extreme cost sensitivity to launch weight, and permitting recovery and repair of expensive payloads.

The shuttle justification is built almost entirely around these economic data for Earth applications. Yet it is true that the potential is created for more distant flights as well. For example, the estimate is that Apollo/Saturn V hardware had an operating cost for round trips to the Moon of $80,000 per kilogram. With the

four new elements of the Space Task Group plan, this operating cost would have fallen to about $800 per kilogram, or only one percent as much. (All figures have to be adjusted for inflation.) In similar fashion, planetary flights fall drastically in cost, and even allowing for all the special payloads that might be required, a Mars expedition in the late 1980's might be priced at a figure far closer to $10 billion (1971 dollars) than to the former estimate of $100 billion (1971 dollars). This is not a question which must be decided now, but as elements of the four types of reusable vehicles may be added to the national capability, each justified on other ground, we may find that we have kept our options open for this later period in our history. The unmanned planetary explorers may bring back the data which will answer whether there is a reason to send men as well.

As already indicated, the Soviet Union has talked more positively about manned flight to the planets, and it is hard to doubt their ultimate intentions in this regard as one studies their total program effort. But to carry out such flights will face them with the same technical and financial questions which the United States will have.

This brief review does not assess the ultimate consequences of pursuit of such goals or failure to undertake them. Some people are already convinced that no set of circumstances would warrant the effort. Others are hardly deterred by the difficulties, expense, or uncertain results. It is hard to accept philosophically that mankind would forever exclude the possibility of visiting most parts of the Solar System. The late President Eisenhower saw practical reasons for limiting space expenditures, but even his first public report on space goals accepted in principle flights by men to Mars, as have most other U.S. Presidents since that time.

G. Can the two countries cooperate as well as compete?

This is the hope of well-intentioned people everywhere. In some sense, cooperation already exists. There is a considerable exchange of information at meetings of

scientists and engineers, and data are filed at the United Nations. There have been treaties negotiated on excluding weapons from space, not making territorial claims to other celestial bodies, and rescuing astronauts.

Further, there has been trading of space-collected weather pictures over the "cold line" between Suitland, Maryland and Moscow. There was a joint effort to write a multi-volume textbook on space biology. There has been some coordination of efforts on geo-magnetism. In 1970, negotiations also opened on possible common designs for docking attachments to facilitate space rescue or joint work in future generations of spacecraft, both Soviet and American. In 1975 the United States had biological experiments carried on Kosmos 782 and in 1977 had similar experiments carried on Kosmos 936.

But the mid-1960's big question of Russians and Americans going to the Moon together was asked more in a rhetorical sense than as a concrete offer by either side. Each side probably was somewhat reluctant to pursue such a goal too openly during any period that one or the other was markedly ahead. Nor has either been willing to give up any basic, independent capability to operate in space, which might be implied by such a division of labor as specialization in launch vehicles or spacecraft.

Two principal motives for cooperation offered have been to lessen tensions politically, and to save money. The question of tensions may be more influenced by broader political issues than technical cooperation. Money savings are problematical, except as someday sharing of data might permit a division of missions as between one planet and another, for example. Useful also are the proposed biomedical data exchanges.

The most ambitious joint program was the Apollo-Soyuz Test Project (ASTP) already described. ASTP came off technically without a serious hitch, but was quite controversial. Challenges were made on the grounds of cost, safety, technology transfer, and Soviet image-building. Because the program was largely dead-ended technically, and the amount of science was slight in relation to the investment, the cost was criticized. Unknown problems of systems compatibility and worries about Soviet

equipment unreliability led to some political demands that the program be suspended for much more detailed studies. There were worries that the United States was giving away more technology than it was gaining. A Soviet program which had faltered was presented to the world as an equal partner through ASTP. The Soviet investment in test flights and back-up hardware was probably at least as great as the U.S. investment in the docking module which it supplied. Most of the safety charges lodged against the Russians were based upon launcher problems such as their April 5, 1975 aborted Soyuz, not wholly applicable to the space orbital meeting. Both sides were rather careful not to give away really private technology. The Russians surely gained first hand insights into NASA management methods and documentation, and the Americans visited Soviet facilities and people never before available. It is not clear that the Soviet program needed a political boost in image considering its massive size and many successes.

More crucial is the question: Where do the Americans and Russians go next in cooperation? No specific follow-up of major proportions has been agreed to yet. At least the technical capability to work together has been demonstrated. New discussions of plans for joint space flights began in 1977.

It should not pass without mention that aside from the question of U.S. cooperation with the Russians, for many years this country has had a broad program of joint work with about 75 other nations in space. Those nations put in their own funds, and U.S. funds are used only for those aspects of flights which on their merits won competitions with rival U.S. proposals for allocation of the limited number of approved flight missions. Cooperation with the U.S.S.R. therefore is not an exclusive kind of arrangement although it has the potential for larger operations simply because of the scope of the total Soviet space program.

No assessment of the overall prospects can be made successfully without forecasting the future political climate, which is beyond the goal of this paper.

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X. APPENDIX

Conversion of Metric to English Measures

All data in this report have been quoted in metric rather than English measures. Only a few such measures are required in this study. For the convenience of readers not as familiar with metric measures, the following brief conversion table is supplied, related only to measures used in this report:

1 kilogram equals 2.20462 pounds avoirdupois

1 kilometer equals 0.6214 statute miles

1 cubic meter equals 35.31 cubic feet

1 meter equals 3.28083 linear feet

1 gram equals 0.03527 ounces avoirdupois

1 centimeter equals 0.3937 linear inches